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ASBESTOS

ITS PROPERTIES, OCCURRENCE, AND USES

A CANADIAN CHRYSOTILE QUARRY.

"Of steely colour and of wondrous might
Arcadia's hills produce th' asbeston bright;
For kindled once it no extinction knows,
But with eternal flame unceasing glows;
Hence, with good cause, the Greeks asbeston name
Because, once kindled, naught can quench the flame."

"LAPIDARIUM."

A CANADIAN CHRYSOTILE QUARRY.

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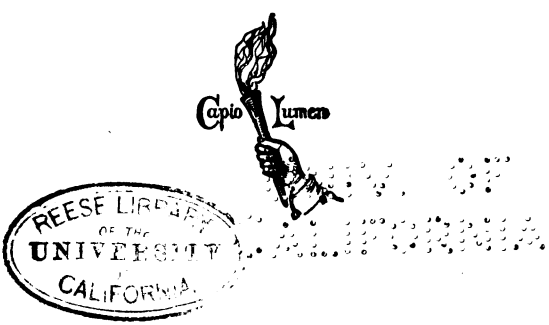
ASBESTOS

ITS PROPERTIES, OCCURRENCE, & USES

WITH SOME ACCOUNT
OF THE MINES OF ITALY AND CANADA

By ROBERT H. JONES

With Eight Collotype Plates and other Illustrations



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PREFACE.

SOME three years ago the writer of the following pages issued, in pamphlet form, a short account of the Canadian Asbestos Mines, appending thereto a few pages descriptive of the more important uses to which asbestos was found applicable.

Taking a keen interest in the subject, and believing that, in the near future, there would be few branches of practical mechanics, of art or of industry, in which asbestos would not find a place, he has carefully noted the new uses which are continually suggested, and the processes of manufacture which are from time to time devised for its further utilisation.

He trusts that in endeavouring to weave the contents of a somewhat voluminous note-book into a connected and readable form he has been in some degree successful; his object being to give a synopsis of all that is known on the subject generally, so that those who, like himself, are interested in this singular mineral, may find all the details ready to hand without the labour and time he has had to expend in looking them up. Much of the most important of these are buried in blue books, pamphlets, and articles in magazines and scientific journals, published in England, America, and on the Continent of Europe, a considerable part of which are not at all times readily accessible to the general reader. He hopes by this means to stimulate a

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spirit of enquiry which will lead to a search for the mineral in other lands, and tend to develop the uses of some of those varieties which now are assumed to possess but little commercial value.

A very large amount of information is derived from the Geological Reports from time to time issued by the Dominion Government, and from the writings of the members of the Geological Survey of Canada, especially those of Dr. Ells, a very high authority on all that relates to Canadian asbestos.

In every case the writer has sought the highest and best authorities for the statements made, which, wherever possible, he has given in the writer's own words, indicating at the same time the sources from which his information has been derived, so that the reader may better appreciate its authenticity and value than if it were given as his own.

In preparing the following pages for the press he is glad to have an opportunity of expressing his grateful acknowledgments to Mr. E. W. H. Eady, of Southampton, whose scientific acquirements and practical skill in photography and photo-micrography have been freely placed at his disposal, and have thus enabled him by pictorial delineation more clearly to indicate many points which would have been somewhat difficult of elucidation without such generous assistance.

R. H. J.

LONDON,

1*st September*, 1890.

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ASBESTOS.

INTRODUCTORY.

NATURE AND PROPERTIES OF ASBESTOS—Essential Characteristics—Charlemagne's Tablecloth—Cremation Wrappings—Difficulty of Weaving—Napkins—The Sudarium—Marco Polo—Indian Dresses—Cere-cloth—Sacred Fires—Rock Crystal—Lamps—Gibbon—Amianthus—Potstone—Madame Perpenti—Dr. Bruckmann—Aldini—Canadian Asbestos.

ASBESTOS is one of the many marvellous productions of inorganic nature. It is found in a singular variety of forms, and in some shape or other in almost every part of the world. Some few, only, of the many varieties known, are at present found useful, but those few are applicable to a surprising number of very dissimilar uses. In itself asbestos is a physical paradox, a mineralogical vegetable,* both fibrous and crystalline, elastic yet brittle, a floating stone, but as capable of being carded, spun, and woven as flax, cotton, or silk.

Occupying the position of a connecting link between the animal, vegetable, and mineral kingdoms, it possesses some of the characteristics of all three. Whilst in appearance as light, buoyant, and feathery as thistledown, it is, in its crude state, as dense and heavy as the solid rock in which it is found; ostensibly as perishable as grass, it is yet older than any order of

* "All stones, metals, and minerals are real vegetables, that is, grow organically from proper seeds, as well as plants."—Locke's "Elem. Nat. Hist.," c. viii.

"Whenever a unit, an individual, develops in nature, growth is the first condition. This is equally true of inorganic as of organic bodies. . . .

60

animal or vegetable life on earth. So little, indeed, is it affected by the dissolving influences of time that the action of unnumbered centuries, by which the hardest rocks known to geologists are worn away, has had no perceptible effect on the asbestos found embedded in them. Whilst the greater portion of its bulk is composed of the roughest and most gritty materials known, it is really as smooth to the touch as soap or oil. Apparently as combustible as tow, the fiercest heat cannot consume it, and no combination of acids will affect the appearance and strength of its fibre, even after days of exposure to its action.*

Its peculiar properties thus endow it with practical indestructibility, and enable it to resist decay and destruction under almost every condition of heat and moisture, even preserving it from undergoing any deleterious change when brought into contact with superheated steam or grease; nor is it even worn away or rendered useless by the severe treatment it undergoes in connection with marine, hydraulic, or other engines. So little influence of a chemical nature does it exert over any metal with which it is brought in contact that, if a joint be broken, the surfaces will be found entirely free from corrosion. Its incombustible nature and slow conduction of heat render it also a complete protection from flames. In its crude state, therefore, it is keenly sought for, whilst, as a manufactured article, it must necessarily command a high price until more extensive sources of supply than those at present available are discovered.

The most important characteristic of asbestos is its fireproof quality, which was well-known to and appreciated by the ancients. In our own time it is also known as a useful non-

Growth, the addition of homogeneous body substance, is absolutely universal. The inorganic crystal grows by absorbing homogeneous matter from the surrounding fluid medium, which then passes from a fluid into a solid condition. The only difference between the growth of a crystal and that of the simplest organic individual, the cell, is that the former adds the new substance externally, while the latter absorbs it internally."—Hæckel's "Evolution of Man," i., 156.

* Simmonds on "Waste Products and Undeveloped Substances."

conductor of heat and electricity, as well as for its important property of practical insolubility in acids. Some varieties are said to have resisted a temperature as high as 5,000° Fahr.; but, although it is absolutely infusible, except at very high temperatures, in the hydrous varieties its fibres lose their flexibility and become brittle at a temperature sufficiently high to effect, even partially, its dehydration.

In former days, cloth made of asbestos was cleansed by passing it through fire,* by which, of course, a charcoal fire is understood. It is related of Charlemagne (or, according to some writers, Charles V.) that having one of these cloths in his possession he, to the astonishment of his guests, occasionally amused himself by throwing it on the fire and afterwards withdrawing it, cleansed but unconsumed.†

Its fire-resisting properties were, however, known long before Charlemagne's day, although the difference between the manners and customs of ancient and modern times has caused it, like many other things, to be somewhat differently appreciated by us.

The Romans, who drew their supplies from the Italian Alps and from the Ural, believed it to be of vegetable origin, the

* "Amiantus alumini similis nihil igni deperdet."—Pliny, 36. "Quod ignis adeo non inquinet ipsius splendorem, ut etiamsi in eum conjicitur sordidus, nihil deperdens, nitidus et splendens extrahatur."—Agricola, 609.

† As a modern pendant to this well-known legend, the following is current in Quebec. A labouring man, who had left the old country to seek a better fortune in the Dominion, found employment at once on arrival in one of the many lumber yards on the St. Lawrence, where his energy and activity, supplemented by great bodily strength, soon secured for him a good position. It so happened, however, that one evening, on returning from their daily toil to their common apartment, some of his fellow-workmen saw him deliberately throw himself into a seat, kick off his boots, and then pull off his socks, and, having opened the door of the stove, coolly fling them in on to the mass of burning wood. Possibly no particular notice would have been taken of this, judged as a mere act of folly and waste on the part of the new-comer; but when, almost immediately afterwards, they saw him again open the stove door, take out the apparently blazing socks, and, after giving them a shake, proceed just as deliberately to draw them on to his feet again, that was a trifle too much! Human nature could not stand that. Consequently the horrified spec-

silky appearance and unctuous feel of the fibre contributing to the idea that it was an organic substance; silk itself, according to Herodotus (3, 106), being a kind of wool which grew on trees. According to him, they made a kind of cremation cloth of asbestos, in which to enwrap the bodies to be consumed on the funeral pyre, so that the ashes and unconsumed particles of bone might be kept separate from the remains of the fuel, for preservation in vases or in the family urn. In this wrapping, apertures were of necessity left to allow of a free passage for the flames. It would not appear, however, that such a cloth as this could very frequently have been so used on account of its expensiveness. Pliny specially mentions it as a rare and costly cloth, the funeral dress of kings.* Assuming its vegetable origin, he calls it linum vivum,† the difficulty

tators, having for a moment looked on aghast, fled precipitately from the room. To them the facts were clear enough. This, they said, was no human being like themselves; such hellish practices could have but one origin. If not the devil himself, this man certainly could be no other than one of his emissaries. So off they went in a body to the manager and demanded his instant dismissal, loudly asseverating that they would no longer eat, drink, or work in company with such a monster. Enquiry being at once set on foot, it turned out that some time before leaving England the man had worked at an asbestos factory, where he had learned to appreciate the valuable properties of the mineral; and being of an ingenious turn of mind, he had managed to procure some of the fiberised material and therewith knit himself a pair of socks, which he was accustomed to cleanse in the manner described. He was, as has been said, an unusually good workman, consequently his employers had no wish to part with him. Explanation and expostulation, however, were all in vain; nothing could remove the horrible impression that his conduct had made upon the minds of his superstitious fellow-workmen; go he must and did, nor could the tumult be in any way allayed until he had been dismissed from his work and had left the yard.

* "Des suaires dans lesquelles on enveloppait le corps des grandes personnages."—Jagnaux, "Traité de Min." "Die Gewänder, deren man mehrere wieder abgefunden hat, waren aber so kostbar als Perlen."—Quenstedt.

† "Plinius handelte ihn als linum vivum bei den Pflanzen ab;—'nascitur in desertis adustisque sole Indiæ, ubi non cadunt imbres, inter diras serpentes, assuecitque vivere ardendo.'"—Quenstedt, "Handb. der Min." "Lana montana."—Agricola.

of weaving which, he says, was very great on account of the shortness of the fibre, which is a somewhat singular reason to give, seeing that he was not speaking of chrysotile, to which that remark might have applied, but to the Italian mineral, amianthus. Judging, however, from modern experience it would seem that shortness of fibre could not have been the only, or indeed the main cause of the difficulty, and it would be singularly interesting to know how the difficulty, whatever it was, was in those days surmounted. It is supposed that the weaving process was achieved by mingling organic fibres of some kind, probably flax, with the asbestos, and then, aided by a liberal supply of oil, weaving both fibres together, the oil and flax being afterwards got rid of by exposing the cloth to a red heat; which, in point of fact, was the mode actually adopted in modern times, until, after long-continued experiment, means were found of overcoming the refractory nature of the fibre.* In one of the asbestos cloths shown at the Vatican Museum, Mr. Boyd could plainly distinguish the vegetable matter woven in with the mineral fibre. Varro and others also make mention of these cloths, but give us no information on the point of manufacture. "Most kinds of asbestos," Mr. Simmonds says, "cannot be spun or woven without the intermixture of cotton or linen fibre, as the asbestos fibres are not quite long enough. The intermixture of longer fibre makes the operation

* "There is nothing more wonderful in the intellectual history of mankind than the skilful management (by the ancients) of many processes in the arts, the true nature of which was not understood till ages and ages afterwards. Thus, although zinc was scarcely known as a distinct metal until almost a century since, and almost within the same period, one of its commonest ores, calamine, was held in so little estimation in Great Britain, that it was frequently used as ballast for shipping, yet that same ore was used before the time of Aristotle for the purpose of making brass, and to that purpose it is principally applied at the present day."—Second Bridgewater Treatise. In regard to which it may be remarked that Pliny noticed that if copper was placed in close proximity to calamine, it, on being exposed to heat, increased in weight by absorption of the calamine, thus anticipating the conversion of copper into brass by cementation.

quite easy, and when the fabric is entirely ready it is simply placed in the fire, when the combustible linen or cotton is burned out and the incombustible texture remains." Such cloths as these, after all, must have been very wretched-looking skeletons of what was intended, and perhaps were objects rather of curiosity than of any practical utility.

In regard to the so-called napkins, which are often mentioned, there can be no doubt that these, as well as some articles of dress, were, in ancient days, when wood was the principal fuel used, occasionally made of asbestos, and cleansed in the manner described. Pliny, referring to this practice (19, 1), avers that thereby "such things were returned far fairer and whiter than they could possibly be rendered by the air or water." Some of these napkins, supposed to have been used by the Emperors, are still to be seen in the Vatican library, and in the Museums at Naples; in the latter case having been found at Pompeii, and in the former there is a shroud of considerable length which was found perfectly intact in a sarcophagus in the Via Prænestina, in 1702. Some of the cloth of which these are made is so identical in appearance with that manufactured at the present day that only an experienced eye could detect the difference. The Pope is said to have a cloth of the kind in his possession, in which he keeps the Sudarium of Our Lord, the cloth having been sent to one of his predecessors as a costly gift by the Great Khan.

That asbestos cloth was really manufactured in the country of that potentate is corroborated by Marco Polo, who tells us that when (about A.D. 1250) he was traversing the region then known as the Great Empire of Tartary, but which now forms part of Russian Siberia, where, as we know, the mineral exists in abundance, he was shown some cloth which withstood the action of fire, and which the people told him was made from the skin of the salamander. But Marco was far too old a traveller to be caught by any fable about a woolly lizard, so he very carefully examined the material, which he then found to be made of "a fibrous mineral called amianto." Following up his enquiries, he elicited the information that when the ore,

from the fibres of which the cloth was made, was first dug out from the mountain and broken up, it strung together, and formed a thread similar to wool; this was then dried and pounded in a mortar, when, after washing out the impurities, the clear thread remained behind. This thread was afterwards woven into cloth, which, at first, had a somewhat dingy appearance, but, after being subjected to the action of fire, became "white as snow, and without a stain."

When the mode adopted, at the present time, of extracting the mineral from the rock, and preparing it for use, comes to be considered, we shall see with what singular accuracy the process has been thus described. It is matter of regret, therefore, that the painstaking traveller did not push his enquiry still further, or find an opportunity of witnessing the manufacture, so that he might have told us, in the same lucid manner, how the weaving of the fibre was accomplished. The dinginess of colour he refers to is easily accounted for by the handling.

Under the Pharaohs a coarse kind of cloth was specially made as a cere-cloth, to cover the relics of humanity, and so help to preserve them from the ravages of time, the body having been first embalmed, by the undertaker, with aloes and subtle essences, in order to prevent the survivors from suffering from the pestilential exhalations, which would otherwise have emanated from them.

The religious care with which the ancients guarded from extinction the Sacred Fires, in the Temples of the Gods, caused them to use asbestos as an auxiliary, the flame having been first started by means of a crystal sphere. * The lamps, also,

* Rock crystal, a pellucid quartz, pure silica. From κρύος, ice, κρυσταλλος, pure ice. This latter term was first applied to crystals of quartz only, which, by reason of its transparency, freedom from colour, and frequent enclosures, was thought to be water congealed by intense cold.—Pliny, 27, 9; Sen., "Nat. Quæst.," 3, 25. That it has once been liquid is proved by its enclosures. Boyle, however, showed it to be heavier than an equal bulk of water, by more than two to one, ice being bulk for bulk lighter than water. Pliny says that "the best cautery for the human body is a ball of crystal acted on by the sun" (37, 10); but

which were used by the Vestal Virgins are stated to have been furnished with asbestos wicks, the fine fibres of which would well serve to draw up and feed the flame with oil, * whilst themselves remaining unconsumed. Strabo † and Plutarch ‡ both speak of these lamps, calling them ἄσβεστα (perpetual). Pausanias § also mentions them, specially alluding to one made of gold, for Minerva, by Callimachus, an Athenian artist, respecting which he says that, although it was kept ever burning, both by day and night, it was only supplied with oil once a year. The wick, he says also, was made of Carpasian linen, "the only linen which is not consumed by fire," the name being derived from Carpasius, in Cyprus, where it was first manufactured; no doubt being the same as that mentioned by Strabo, as made of Carystian stone, an asbestos found at Carystus, in Eubœa. ‖

With one more instance of its use by the ancients, we may leave this part of the subject. We are told by Gibbon ¶ that, at the Siege of Auximum, the Roman General, in order to poison the waters, and thereby tame the stubborn spirit of the defenders of the place, cast into the stream (among other

the following extract from the "Lapidarium" indicates a still more singular virtue supposed to be inherent in rock crystal:—

"Crystal is ice, through countless ages grown
(So teach the wise) to hard, transparent stone;
* * * * * *
Dissolved in honey, let the luscious draught
By mothers suckling their lov'd charge be quaffed,
Then from their breasts, as sage physicians show,
Shall milk abundant, in rich torrents flow."

* "Le mot asbeste vient de ce que dans l'antiquité on employait cette substance pour faire des mèches qui, alimentée *par une source de bitume*, fournissait des lampes perpetuelles."—Jagnaux, "Traité de Min.," 551.

† P. 396. ‡ "De Def. Orac.," v. 2, 410 B. § Lib. 1, 26.

‖ When Caron was experimenting on magnesia, in 1868, with a view to its application as a refractory material for crucibles, he used the native carbonate of magnesia from Eubœa, where it occurs compact and tolerably hard, with traces of lime, silica, and iron, and occasionally, he says, "matières serpentineuses," which would greatly lessen its fusibility.

¶ "Decline and Fall," c. 42.

noxious things) "quicklime, which is named, says Procopius, * *titanos* by the ancients, by the moderns *asbestos*, meaning by the moderns the men of his own time, *i.e.*, the sixth century." But what Procopius here calls asbestos was evidently not amianthus; possibly it was a variety of gypsum, which occasionally has an asbestiform appearance, although it may be easily distinguished from asbestos by its softness and by its becoming an opaque white powder immediately, and without fusion, before the blow-pipe; whereas, although a single fibre of asbestos will fuse to a white enamel, the material itself is unaffected by fire. When, however, dealing with such statements as these, we must bear in mind that mineralogy, as we understand it, was only very imperfectly known to the ancients; consequently, things quite distinct from one another were, in former days, often comprehended under one generic term, and this not only because their appearance was very similar, or because they might possibly agree in some striking quality, but sometimes even on account of their place of origin, and, in a few special cases, because the uses to which they were applied were somewhat similar. It has always, therefore, been a matter of extreme difficulty to identify the names of minerals, as formerly employed, with those they were intended to indicate. † To give one instance, white clay or chalk, quicklime and the sulphate of lime, were one and all occasionally called gypsum, although, as a matter of fact, that word was used generally to signify sulphate of lime only. "Calci res gypsum est," Pliny says; but Theophrastus, ‡ who was a far better mineralogist than Pliny, uses the term with a more general signification, as of an earth prepared by fire, in doing which he evidently confounds it with quicklime, as in the paragraph where he says:—"Its heat, on being moistened, is surprising; and, when used for building purposes, the builders break it up, pour water on it, and stir it about with sticks, its heat being such that they cannot touch it with their hands." In another place he compares amianthus to rotten wood, § and

* Lib. 2, c. 29.

† Moore, "An. Min."

‡ *περι λιθων*, c. 29.

§ *αμιανθος λιθος*, v 155.

even such dissimilar minerals as iron ore, quartz, emery, and the diamond were occasionally comprehended under the single term *adamas*.

Professor Ansted, in his "Rambles in Search of Minerals," tells us that certain tribes of Indians make dresses of asbestos, which they cleanse by throwing them into fire.

The variety of asbestos spoken of by Marco Polo as amianto (amianthus) has always been regarded as the most valuable kind, on account of its beautifully long, white, flexible, and delicately arranged fibres. In whatever part of the world it occurs, it is found embedded in the older crystalline rocks. It is seldom found in the United States; never, so far as I know, in Canada. Very beautiful specimens are brought from Savoy and Corsica; indeed, so plentiful is it in the latter island that formerly (its mercantile value being unknown) it was often used, instead of tow, for packing. Dana says that Dolomieu, when there, made use of it for packing up the other minerals of his collection. There is also a fibrous kind of potstone * found there (which, like asbestos, is a silicate of magnesia †), with which the inhabitants manufacture certain kinds of pottery by mixing it with the ordinary potter's clay, obtaining thereby a lighter and more durable vessel than they could get by the use of clay alone.

Referring to the use by the ancients of asbestos in lamps and fires, the mineral, being abundant in Greenland, is used there now by the inhabitants for lampwicks, and certain kinds of lamps are made in England having asbestos wicks, whilst the very common use of it in gas stoves, where the appearance of fire is desired, will be at once called to mind. These modern adaptations of the fibre, therefore, can only be looked on as so many exemplifications of the truth of Solomon's saying that "there is nothing new under the sun."

* Ollite (*lapis ollaris*) from *olla*, a dish. This is an impure soapstone of a greyish green or dark green colour, and usually of a slaty structure. It is found abundantly at Potton in the Eastern Townships of Quebec. See *post*, p. 200.

† So called from a city in Thessaly. There was another city, also of the same name, where, Pliny says, the mineral called magnet was found,

In the general application of asbestos, in modern times, to the several branches of practical mechanics and industrial manufactures, it is to Italy that we are indebted for leading the way. Previous isolated experiments are recorded, but these do not seem to have been followed up, until long afterwards. In the last century, for instance, Professor Bruckmann, of Brunswick, was successful in the manufacture of asbestos paper, on which he caused to be printed a natural history of the mineral, some copies of which book are said to be still preserved in the museum at Wolfenbuttel. And early in the present century Madame Perpenti, of Cône, successfully employed asbestos, not only in the manufacture of paper, but of cloth also, as well as of a kind of coarse lace, with many other articles of a useful character. And it is worthy of note, that in her make of cloth, she made no use of any other fibrous ingredient as an admixture; her process simply consisting of softening the asbestos in water, beating and rubbing it, and finally separating the fibres by means of a comb furnished with fine steel points.

Apart, however, from these and other isolated cases, which no doubt pointed out the way for later experimenters, the important industrial capabilities of asbestos were neglected until quite recently, and not seriously taken in hand until 1850, when the Chevalier Aldini and others conducted a series of experiments, in which they were to a great degree successful, with the object of turning its fire-resisting properties to account for the protection of firemen. And soon after this a Florentine priest, one Giuseppe della Corona, brought to a successful issue his experiments for the manufacture of asbestos millboard.

When, however, we turn to Canada we find that, although the valuable variety of asbestos which occurs in the Dominion was well known to geologists for many years prior to 1877, yet, for all practical purposes, its true economic importance

which he describes as being of a whitish colour, somewhat resembling pumice and not attracting iron. A purer form of magnesia was no doubt meant by Hippocrates (*τῆς μαγνησιης λιθον*) which he mentions as being prescribed as a cathartic, possibly native carbonate of magnesia.

remained unrecognised until that date; and even so recently as 1882 its value may be said to have been generally unknown. In Rand and Macnally's Great Atlas of the World, we do not find asbestos even mentioned, in the copious dissertation to be found there on the trade and manufactures of the Province of Quebec: iron and copper alone being named as the chief mineral productions of that part of the Dominion. And when, in 1886, a little book was prepared, with great care and at considerable expense, for gratuitous distribution in the Canadian section of the Colonial and Indian exhibition of that year, in order to enlighten the world on the capabilities, productions, and mineral resources of Canada, no mention was made of asbestos among the mineral productions of the country, although some good specimens were to be seen there, notably an exhibit by the Johnson Company of Thetford.

From the foregoing it would seem that, even at so recent a date as 1886, no very great importance was attached to this mineral in the country of its production. Now, however, all this is changed: land on the serpentine belt (where the mineral is alone found) is daily increasing in value, and new mines are being sought for and opened; whilst, as the demand for the raw material increases, fresh capital is being furnished, and improved machinery invented and brought into use, for increasing the production, greater care being at the same time used in the cobbing and preparation for market of the raw material.

The uses of asbestos, in the arts and manufactures, are now of so important and varied a character that the main features of these must be treated of in a separate chapter, as even a mere enumeration of the principal among them would run to a considerable length. Indeed, now that it has been demonstrated that a fairly abundant supply of the raw material can, with tolerable certainty, be relied on, at a fairly reasonable cost, there would seem to be no limit to the growing demand, especially as new uses for the mineral are being daily found. This demand will, of course, still more rapidly increase, as the value and almost universal utility of the fibre becomes, by its more extended use, more clearly and widely known.

UNIVERSITY

ITALIAN ASBESTOS. "THE GREY."

CHAPTER I.

VARIETIES AND QUALITIES OF ASBESTOS.

Derivation — Name — Varieties — Description — Granular and Fibrous Structure — Variations — Occurrence — Chrysotile Spinning — General Use.

Deriv.: ἀ, Priv., and σβεσω, I quench.

Called by mineralogists asbes*tus*, the name in its Greek form, as commonly used, ἄσβεστος, signifies unquenchable, unconsumable, endless, "qui peut dure un temps infini." * In Spain and Portugal it is called asbesto, whence asbestino (asbestine), a name applied to asbestos cloth. The French, using the same derivation, call it asbeste (minéral filamenteux et incombustible). In Germany it is termed Steinflachs (stone-flax); and in Italy, amianto (amianthus, from ἄμιαντος, pure, incorruptible), so named because of the simplicity of the means of restoring it, when soiled, to its original purity, by the agency of fire; and in the local vernacular of the French Canadian miners it is pierre-à-coton (cotton-stone), perhaps as expressive a non-scientific designation as can be found, the fibre itself being commonly spoken of as cotton.

Asbestos is a term of a generic character applied to the peculiar fibrous form assumed by several minerals, and not a name given to any one particular species, the asbestiform condition being simply a peculiar form under which many minerals, especially serpentine, occasionally present themselves.

The varieties of asbestos are very numerous. They are all silicates of lime and magnesia or alumina; compounds of silica

* "Αγάπη Ἀσβεστος" (a memorial of) Eternal affection.—Archbishop Benson, *Daily Graphic*, 4th April, 1890. *Vide ante*, p. 8.

(silicic acid) with an earthy base, and the greater part of them hydrated. The bases, lime and magnesia, with the protoxides of lime and magnesia, being mutually replaceable in many of the magnesian silicates, these latter are subject to great variations in colour, density, and other characteristics.* Nearly all the forms are distinguished by having a crystalline fibrous structure, and most of them possess both flexibility and elasticity; in some of them the whole mass is flexible and elastic, in others the fibres only are so.

What may be termed *asbestos proper*, or *true asbestos*, is a fibrous variety of hornblende, or pyroxene, and differs materially from the so-called asbestos of Canada, this last being a fibrous form of serpentine containing 12 to 14 per cent. of water, true asbestos being essentially anhydrous. The anhydrous silicates of magnesia have nothing of the soapy feel, so common among the hydrous species, excepting talc, which is often hydrous.†

The sub-varieties known as mountain wood, mountain leather and paper, and mountain cork, differ in many ways from the more valuable kinds, one of their principal peculiarities being that their fibres, instead of lying parallel across the vein, are so matted and interlaced, that the fibrous structure is not at all times readily apparent. The three first-named are so called from similarity of appearance to the substances after which they are named, and the latter from its extreme lightness, which enables it to float on water, as if it were really cork; its lightness being caused by the loose interlacement of its fibres, forming multitudinous air-cells.

Mountain Wood (*Ligniform asbestos, Bergholz, Holzasbest, Xylotil*) is hard and close grained, and will take a high polish. It is generally of a brownish colour and often bears an exact resemblance to petrified wood, for which, at first sight, it might easily be mistaken, especially when sufficient iron is present to give it the ruddy tinge of decayed wood or bark. Under the microscope, however, the crystal fibre is easily detected, as is also the absence of the vegetable cells which are always to be

* Dana, "System of Min.," 1850, 265. † Dana, *ibid.*

found in petrified wood. The fibres of this variety, though it varies very much in texture, are generally long, curved, and compact, and these will melt to a black slag. Rammelsberg thinks it may be an altered chrysotile.

Mountain Leather (*Bergleder*, *Bergfleisch*), which contains little or no alumina, originates in cases where the fibres "felt" by interlacement, instead of lying parallel. This usually looks and feels very much like kid leather. The varieties which feel greasy and cold contain a mixture of talc, and are called Bergfleisch; when they are poor and warm they become light enough to float on water, and these may sometimes be mistaken for meerschaum.*

Mountain Paper is merely a finer and thinner variety of the last named. It is a papery-looking sub-variety of asbestos, sometimes called fossil paper.

Mountain Cork (*Rock-cork*, *Bergkork*) is a spongy elastic form of asbestos, which has a texture like felt. It is similar to mountain leather, but more elastic and thicker. It possesses the lightness and elasticity of cork, and is usually of a dingy white colour. The composition of mountain cork is as follows:—

Silica	57·20
Peroxide of iron	4·37
Magnesia	22·85
Lime	13·39
Water	2·43
	100·24

Sp. gr., 0·68 to 0·99. Professor Heddle includes these two last under the name of pilolite (πιλος λιθος, feltstone). He procured seven specimens from as many different localities in Scotland, and, having analysed them, found they were essentially hydrated silicates of alumina, magnesia, protoxides of iron and manganese, with some lime, for which the calculated formula is given as $Mg_4\ (Al_2)\ Si_{10}\ O_{27}\ 15\ H_2\ O$. These seven specimens were found in granular limestone, and in veins in granite, sandstones, and slates.

* Quendstedt, 332.

Mountain Flax (*Bergflachs, fossil flax*) is merely a popular name for amianthus.

Chrysotile (*Schillernder asbest*), the form mostly found in Canada, differs materially from some of the other varieties, and is of so important a character that it will be separately described, as will also the principal Italian species.

Blue Asbestos (*crocidolite, krokidolit, Blaueisenstein*) is a totally distinct variety, being a silicate of iron, iron in this replacing magnesia, in the same way as is the case with alumina in the Natal species. It occurs in micaceous porphyry in the Vosges; and very abundantly, in association with beds of iron ore, in the asbestos mountains, Great Orange River, South Africa, about 700 miles from the Cape of Good Hope. It is found in two forms, fibrous and earthy; the former is of a peculiar lavender-blue or leek-green colour, in appearance much like chrysotile, and possessing long, delicate-looking fibres, which are somewhat elastic and easily separable by the fingers. The colour is caused by the large proportion of oxide of iron it contains. The enclosing rock is a dark brown and purplish shale. A good deal of diopside also occurs in the same formation. The technical description of crocidolite is as follows: "Silicate of iron, sodium (magnesium and aluminium), $3\ R''\ O_1\ R''_2\ O_3$. H=4. Sp. gr., 3·2 to 3·6, lustre, silky." But, although described as silky, the fibres generally have the appearance of stocking-wool rather than silk, as would seem to be indicated by its name, which is derived from κροκις (pro κροκὸς, Ger. Flocke), woof, in evident allusion to its wool-like fibres. Its composition is given as—

Silica	51·1
Protoxide of iron	35·8
Soda	6·9
Magnesia	2·3
Water	3·9
	100·0

De Lapperent, in alluding to this form, says: "Masses souvent asbestiformes composées de fibres parallèles très fines, faciles à

separer, paraissent être à l'Arfvedsonite ce que l'asbeste est à l'actinote. Les fibres sont tendres, elastiques et flexibles. Bleu indigo ou bleu-gris ; poussière bleu lavande. Les fibres très déliées fondent à la flamme d'une bougie en devenant rouges ; au chalumeau elles fondent facilement en globule noir magnétique : dans le matras degage de l'eau. Se dissout facilement dans le borax en donnant un verre verte olive. Dans le sel de phosphore laisse un squelette de silice. N'est pas sensiblement attaquée par les acides. On peut la considerer comme un Arfvedsonite dont la chaux aurait disparu." * His analysis does not differ in essential particulars from that given above :—

Silice	51·22
Oxide ferreux	34·08
Oxide manganeux	0·10
Magnesia	2·48
Chaux	0·03
Soude	7·07
Eau	4·50
	99·48

Crocidolite occurs in both its forms in Greenland in association with sodalite, † and at Stavern, in Norway. The fibrous seams or masses of this variety, make an angle of 106° with the opposite surfaces of the seam, according to Haussmann, ‡ who states that a cylinder of it $\frac{4}{100}$ of an inch in diameter supported ninety-one Hanoverian pounds without breaking, whereas one of asbestos $\frac{1}{100}$ of an inch in diameter broke with a weight of 6 oz. This marvellous tensile strength, which is attributable to the large amount of iron in its composition, is neutralised (for present purposes) by a corresponding deficiency of fireproofness, occasioned by the want of lime or magnesia. It is difficult, therefore, to see how this variety is to be usefully employed, in competition with the light-coloured, elastic, but less tenacious, varieties, which usually contain, with a small proportion of iron, a correspondingly larger amount of lime and magnesia.

* "Cours de Min.," 84. † Dana. ‡ "Handb.," 1847, 743.

Breislakite is a woolly-looking variety of fibrous pyroxene, named after Breislak, an Italian mineralogist. This is sometimes called cyclopeite, and is found at Vesuvius and Capo di Bove. The fibres are flexible and the colour reddish brown: it contains silica and alumina, but does not appear to possess any economic value.

Byssolite (from Byssus) is an old name for asbestos, now seldom used. Des Cloizeau says: "On avait donné autrefois le nom de Byssolite à une asbeste gris-jaunâtre qui accompagne souvent les crystaux d'albite du Dauphiné."* And Bauer, speaking of it, says: "Byssolit gleicht graue und blondfarbigen Menschen haaren, aber trotz deiser Feinheit bleibt er glasig spröde, weil er auf Feldspathgesteine mit Adular und Bergcrystals in den Hochalpen einbricht."† It is of an olive-green colour, coarse and stiffly fibrous. It occurs associated with a black oxide of manganese.

A dark green coloured asbestiform mineral, found near the Cow Flat Copper Mines in New South Wales,‡ was shown to have the following composition, and is consequently unworkable:—

Hygroscopic water	1·084
Combined water by difference	1·941
Silica	49·447
Alumina	9·688
Iron sesquioxide	16·330
,, protoxide	5·151
Manganese protoxide	4·389
Magnesia	traces
Lime	11·970
	100·000

Another mineral of a more valuable character is picrolite.§ This occurs in many places, amongst others at Bolton, in the Eastern Townships of Quebec.‖ Its ore is separable into long,

* "Manuel de Min.," 80. † "Lehrbuch," 425.

‡ Liversedge's "Min. of New South Wales," 1888, 181.

§ From πικρος, bitter; "ou qui a une saveur désagréable," in allusion to the magnesia or Bittererde present.

‖ Dr. Sterry Hunt, "Physiology and Physiography of Minerals," 334.

rigid, somewhat elastic fibres; it has a specific gravity of 2·607, and the following composition:—

Silica	43·70
Magnesia	40·68
Ferrous oxide	3·51
Oxide of nickel	traces
,, chromium	,,
Water	12·45
	100·34

Dana describes this as "columnar, the fibres or columns not easily separable, or affording only a splintery fracture." He gives several analyses, from different localities, differing slightly according to the place where found, but all in practical accord with that given above, and all showing important characteristics.

Mr. Donald thinks it probable that movements of the rocks, and resulting heat, may have been intimately connected with the formation of picrolite.

This mineral, called by the miners bastard asbestos, is generally found along the lines of faults in all the asbestos mines, sometimes in very considerable quantities; notably at Broughton, where large heaps of it, some showing singularly fantastic forms, have been thrown out on the dumps.

Another mineral of some value, which is sometimes called non-fibrous asbestos, may, perhaps, be mentioned here. This is really actinolite,* which is found in the State of Maine and many other places in America, at Arendal in Norway, and elsewhere; also in a radiated form (radiated actinolite, the coarse circular fibres in this case being radiated or divergent) in Central Ontario, notably at North Hastings, where it is being worked. It is found in magnesian rocks, such as talc,

* From ακτιν, ακτινος, a ray of light, "trait de lumière," the crystals being arranged in the form of rays (actinote, Strahlstein). "To nourish the vegetation of this earth the *actinic* and luminous rays of the sun must penetrate our atmosphere."—Tyndall. The actinic rays are violet and blue.

steatite, or serpentine, and is used for one or two purposes, for weighting paper and various forms of adulteration, also by Mr. James, of Bridgewater, Ontario, on whose land there is a considerable deposit, for the manufacture of a "patent actinolite cement roof," which seems to have met with considerable success. The roofing material prepared from this actinolite having, for some time, withstood the test of the Canadian climate, with its extremes of heat and cold, may consequently be deemed fit for use in any part of the world.

In order to prepare it for use, the mineral is pulverized in attrition mills, in such a way as to preserve the fibres as nearly intact as possible. It is then put up in bags, which each contain sufficient material, when mixed with a proper proportion of coal tar, to produce the quantity of cement required for a square of roofing, the fibre preventing any cracking or running in the composition. It is entirely fireproof, the coal tar being so effectually absorbed that there is nothing left to burn. It is obvious, therefore, that the material can be used for a variety of other purposes equally valuable, and there can be little doubt that, as the price of chrysotile rises to prohibitive proportions, these forms of actinolite, as well as the tremolite of the New York State, will be more sought after, and will increase in value in proportion as attempts are made to find a substitute for the higher-priced mineral. The specific gravity of actinolite is 3 to 3·2. Asbestiform actinolite resembles the radiated, but the fibres are more delicate. Tremolite graduates into actinolite by an increase in the proportion of iron, but is easily distinguishable by its colour.

There are many varieties besides the above, but these will no doubt be sufficient to show the diversity of form assumed by asbestos in various localities and in different regions; ranging from the silky flexibility of amianthus to the density of mountain-wood and the extreme tenacity of crocidolite. But, in whatever part of the world it may be found, it will be seen that too much attention cannot be paid to its composition, or to its immediate surroundings, so much depending on this for its usefulness in the arts and manufactures.

Both pyroxene * and hornblende † are sometimes called asbestos, the latter most frequently, the former more rarely assuming an asbestiform character. The name, moreover, is frequently used with especial reference to certain amphibolic minerals, such as actinolite, tremolite,‡ and marmolite,§ in

* "Pyroxene is one of the most common minerals. It is a constituent in almost all basic eruptive rocks, and is principally confined to crystalline and volcanic rocks. In different localities it is associated with granite, granular limestone, serpentine, greenstone, basalt, or lavas. The name is derived from πυρ, fire, and ξένος, stranger, Haüy's idea being that this mineral 'was a stranger in the domain of fire,' whereas in fact it is, next to the feldspars, the most universal constituent of igneous rocks." —Dana, "Min. et Lith.," ed. 1879.

† "Hornblende is generally dark green, brown, or black in colour, and often occurs in stout or more slender prisms, or in irregular-shaped granules or patches. It is an essential constituent of syenite or diorite, and is met with likewise as an accessory mineral in many other igneous rocks. Its cleavage is more perfect than that of augite, and often gives it a platy-like structure, the angles between the cleavage planes being 124° 30″ and 56° 30″."—Geikie, "Geol.," 146.

"Pyroxene and hornblende have the same formula, and under this there is but one difference of any importance, viz., that lime is a prominent ingredient in all the varieties of pyroxene, while it is wanting, or nearly so, in some of those of hornblende. It is difficult to distinguish hornblendic asbestos from the pyroxenic, except by noting its association with known varieties of one or the other minerals." —Dana.

"La hornblende ne diffère de l'actinote que par une proportion plus forte de l'oxyde de fer; à mesure que le fer augmente, la couleur verte de l'actinote devient de plus en plus foncée, passe au noir par degrès insensibles de telle sorte qu'il est impossible d'établir une ligne de démarcation bien nette entre ces deux substances."—Jagnaux, 554.

‡ "So called from the name of the place, Tremola, Mont St. Gothard, where it was found. It commonly occurs in dolomite or granular limestone. Actinolite is found in the greatest perfection in talcose rocks. Tremolite and the pale varieties of hornblende, containing no iron, fuse readily to a glass, nearly transparent to a milk-white; the lighter coloured varieties, containing iron, fuse to a dark yellowish glass."—Dana.

"La tremolite lorsqu'elle s'altère et devient hydratée manifeste une tendance marquée à se deviser en fibres flexibles, à éclat soyeux, capable de former par leur enchevêtrement de veritables tissus minéraux."—De Lapparent, 376.

§ A thin foliated variety, so called before it was known to be serpentine; it contains a good deal of water.

which long capillary crystals occur, forming a compact fibrous mass, the individual crystals generally lying side by side, in parallel lines, at right angles to the walls of the vein, *i.e.*, to the cooling surfaces. But it must be understood that these conditions will be found in very varying degrees in different varieties of the mineral. In amianthus,* for instance, the fibres of which are of a singularly delicate character and beautifully arranged, the crystals are very flexible and are easily separated by the fingers; whereas, in the commoner varieties, the crystals are of a much coarser character, are more difficult to separate, are frequently interlaced or irregularly disposed, and possess but little flexibility. Many of these last are of such a brittle siliceous texture as to be of little or no economic value: they usually exhibit a dull green colour, are somewhat unctuous, and occasionally, but only rarely, display a pearly lustre. Sp. gr. usually about 2·7.

One of the most valuable properties of asbestos is its infusibility. Under the blowpipe a single fibre will fuse into a white enamelled glass or opaque globule, but in the mass some varieties have been known to resist the most intense heat without any visible effect. Chrysotile, however, if exposed for some time to long-continued heat will lose somewhat of its tenacity and silkiness, and become rough and brittle.†

When of a light colour, or some light shade, it is usually found to be tremolite or actinolite. The ore found in the celebrated seam at East Broughton was, like the serpentine in which it was enclosed, of a singularly light (yellowish green) shade, but this was fully equal, if not superior, to any that has since been found in the darker rock, which usually carries the finest quality.

Tremolite, the magnesia-lime variety, is especially common in limestones, particularly magnesian or dolomitic; the compact tremolite, called nephrite, is found in talcose rocks or schists; actinolite, the magnesia-lime-iron variety, in steatitic rocks;

* ἀμιαντος λιθος, Dioscor., v. 155.

† See *post*, p. 94.

and brown, dark green, and black hornblende, in chloritic schists, mica schist, gneiss, and in various other rocks.

Asbestos commonly occurs in crystalline rocks of metamorphic origin,* its infusibility being due to the large proportion of magnesia in its composition; which, like lime, has proved absolutely infusible at the highest temperatures attainable in furnaces or otherwise. The more delicate varieties, presenting the lustre of satin, as we have seen, are usually termed amianthus, though much so called is chrysotile† or fibrous serpentine, both of which are hydrous. As a mineral it has been often described, but apart from its igneous origin,‡ no satisfactory theory has yet been advanced to explain its occurrence, or the conditions which have led to its assuming this peculiar form. Dr. Ells,§ whose intimate knowledge of all that relates to Canadian asbestos is well known, says, "it is still an open question."‖

* "Metamorphism consists in the re-arrangement of the component material of rocks, and notably in their re-crystallisation along particular lines or laminæ. It is usually associated with evidences of great pressure, the rocks in which it occurs having been corrugated and crumpled, not only in vast folds, but even in such minute puckerings as can only be observed with a microscope."—Geikie's "Geol. Sketches," 326.

† "L'amiante, que l'on emploie dans l'industrie, provient généralement du Canada; il est fibreux, blanc et tres réfractaire."—Jagnaux, 1885, 551.

‡ "Prestwich divides igneous rocks into *volcanic*, or such as have been ejected or have welled out on the surface and have, therefore, cooled and consolidated rapidly, and *plutonic*, or such as have been formed under conditions of depth and pressure and have cooled slowly, thereby receiving a more or less distinct crystallisation of the component minerals."—"Chem. and Phys. Geol.," 34.

"Plutonic rocks are of igneous or aqueo-igneous origin, formed at a great depth and under great pressure of superincumbent rocks; they have melted and cooled very slowly so as to permit them to crystallise. They contain no tuffs or breccia, like the volcanic rocks, nor have they pores or cellular cavities. They comprehend granites, syenites, and some porphyries, diorite, tonalite, and gabbro."—Lyell.

"The plutonic (granitoïde) rocks and the volcanic and porphyritic (trachytoïde) present evidence of two distinct periods of crystallisation, the products of which may be easily discriminated."—Levy.

§ Dr. R. W. Ells, of the Geol. and Nat. His. Survey of Canada.

‖ Geol. Report, 1886.

One of the highest living authorities on geology and mineralogy remarks that there is very little to be said in regard to chrysotile that is special to this particular mineral; it is an example of fibrous crystallisation due to crystallising across a fissure, but why it is so finely fibrous cannot at present be explained, except by stating that this is the way with serpentine. When first formed the serpentine is probably in a soft or pasty state* and contracts as it hardens (as if from drying) and in thus contracting breaks into thin, irregular, usually nearly parallel, plates, flat, incurving; and in the intervals between these plates the serpentine crystallises in the fibrous form we call chrysotile. Sometimes there are many such layers to an inch, and in other cases the fibres are several inches long.

Professor Dana refers, but only in a general way, to this important point. In his chapter on Theoretical Crystallogeny,† he says: — "In aggregated crystallisations there is a mass of material entering into the solid state together, and no opportunity exists for single crystals to perfect themselves. While a liquid mass is cooling, whenever the temperature of solidification is reached, at numberless points throughout the mass, crystallisation will begin, and together an aggregation of crowded crystals or grains is produced, with no external regularity of form; in other words the *granular structure*. The same will happen in a crystallising solution if the process goes on rapidly.

"When a solution is spread thinly over a large surface minute crystalline points encrust the whole, and if the solution be gradually supplied as crystallisation goes on, it is obvious that the minute points may elongate into crowded prisms of fibres, producing a *fibrous structure*. Such a structure is common in narrow seams in rocks, and the fibres are usually elongated across the seam."

* Serpentine is frequently found in a pasty state in Italy. Also at the Megantic mine in Coleraine, Quebec. It is here so soft when first taken out as to be compressible between the thumb and finger, but hardens on exposure to the atmosphere.

† "System of Min.," 1850, 124.

This latter paragraph would seem to refer to chrysotile rather than to asbestos; the crystals of the former being elongated across the seam in the precise mode described, whereas the capillary or filiform fibres of the latter are frequently tufted or bundled up in irregular masses, and are often so compactly cemented together by some foreign substance as to require treatment in the boiling tanks and thorough beating and rubbing to rid it of the cementing material before submission to the carding machine.

It is much to be regretted that this interesting subject has not yet received more attention from scientists; we can only hope that ere long (in the words of Professor Dana) "the entrance to one of the innermost recesses of the works of nature will be thrown open, and that the qualities of atoms and molecules, their forms and peculiarities, will soon be understood."*

The phenomena of crystallisation are an intensely interesting study, not only on account of the great beauty of some of the forms, but also of the mathematical regularity and precision with which the process is accomplished.† Although ignorant of the manner in which the majority of crystals are formed in the vast laboratory of nature we can crystallise an immense number of substances, watch their numerous intricate modes of formation, and that even in the smallest appreciable quantities, when aided by the microscope. The formation of artificial crystal may be readily effected, and the process seen, by simply placing a drop of the saturated solution of any salt upon a previously warmed slip of glass.

Mr. Simmonds, when referring to fibrous minerals possessing the chemical composition of augite or amphibolite, says:—"In all these minerals a portion of the magnesia is displaced by

* "System of Min.," 1850, p. 125.

† "Here is a solution of common sulphate of soda or Glauber salt. Looking into it mentally we see the molecules of that liquid, like disciplined squadrons under a governing eye, arranging themselves into battalions, gathering round distinct centres, and forming themselves into solid masses, which, after a time, assume the visible shape of the crystal now held in my hand."—Tyndall's "Fragments of Science."

basic water, and it is exactly the presence of this water which appears to give to these minerals the fibrous structure, and in general causes the crystalline structure to be found with one long axis, obliterating all sideward aggregations of molecules." *

When the prismatic concretions become very narrow the fibrous structure originates. Minerals may have either a parallel-fibrous structure, as is seen in gypsum, calc-spar, &c.; an irregularly-fibrous structure, as in augite or hornblende; matted, as in rock-cork, or radiated, as in actinolite, &c., where the fibres radiate from central points.

Minerals presenting a fibrous structure are sometimes said to be the result of a disturbed crystallisation, although the systematic perfection of some of them would seem to be at variance with this idea. Possibly the fibres of asbestos, like those of some other fibrous minerals, have been produced by the same process of crystallisation which has given rise to the long acicular crystals occasionally found in quartz; and asbestos may perhaps be considered an extreme example of crystallisation in the fibrous form; the crystallisation having evidently taken place under conditions of high temperature and extreme pressure. This pressure may have been caused either by the weight of the superincumbent mass, or by the action of gas, in the same way as liquid steel is compressed in hermetically-sealed ingot moulds by carbonic acid introduced into the top of the mould, the heat of the molten metal, in that case, evaporating the acid when the confined gas exerts a very high pressure upon the metal. M. Gosselet, referring to crystalline minerals generally, says they owe their origin to the action of superheated water in the rock,† in this agreeing with Professor Dana, who says that the great promoter of metamorphic changes is subterranean heat, acting in conjunction with moisture and, usually if not always, under pressure.‡ It is admitted that rapidity of cooling tends to produce the glassy condition of minerals, whilst slow cooling

* "Undeveloped Substances," p. 467.

† Report of Geol. Congress, 1888. ‡ 1850, p. 124.

is the condition most favourable to crystallisation; it may, therefore, be that the more intense the previous heat, the more extreme the pressure, and the slower the process of cooling, the finer would be the resulting crystallisation. And this view seems to be supported by the fact that the heat, by which the production of the fibrous mass was generated, necessarily proceeded from below upwards, whilst it is a matter of daily observation at the mines that the deeper the fibrous veins are followed down into the rock, and the harder and more compact the rock becomes, the finer and purer the fibre is found to be. This is a matter of no slight importance to the miner, because the proportion of the inferior grades, which are of much less value, diminishes in a corresponding ratio; the inferiority of these mainly resulting from surface influences acting upon the shattered rock.

When Mr. Moseley was watching the molten lake at Kilauea,* he saw the smooth surface become cracked in all directions by contraction on cooling, whilst all below was glowing hot. It may be that cracks such as these, formed by contraction of the cooling crust of the earth, originated the fissures in which the asbestos lies, and that when the molten mass below had, by gaseous agency or the explosive power of steam, been forced upwards, so as to fill the fissures, the cooling process commenced. The walls of the vein, that is, the cooling surfaces, or rather the wall, for the fibres grow from one side only, would first become drusy, the point of the minute crystals thus formed on the inner cooling surface forming the poles of attraction; and these, becoming gradually elongated, would eventually reach and then become stopped by the opposite wall of the vein, the result being layers of the filiform or capillary crystals constituting the asbestos mineral, compacted into a solid mass, as we find them, by the intense pressure. The difference in the quality of the asbestos would result from the component parts of the molten mass which had thus become crystallised; hence, the lower veins would of necessity be of finer quality and freer from impurities than those nearer

* "Notes by a Naturalist on board the *Challenger*," 501.

the surface, where extraneous matters would be more likely to intrude, and where solutions of metallic oxides, resulting from surface exposure, could by infiltration through the shattered rock, or by the planes of cleavage, exercise a deleterious effect on the cooling mass.

In regard to metallic veins, M. Simonin remarks that metallic emanations reach the fissures in one of two ways. Either they are deposited in the fissures, which constitute the veins, in the state of vapour, which he calls *the dry method*, as in the craters of volcanoes or the chimneys of smelting furnaces; or in a state of chemical precipitation by *the wet method*, as in the solutions of our laboratories. The rich family of precious stones, he adds, seem to owe their perfection to the same cause. Volatilised in the clefts of the igneous rocks, these stones are there turned into brilliant crystallisations—"the tears of nature."*

Turning from theories of formation to the mineral itself, it may be remarked that, as a general rule, asbestos of good quality is only found in serpentine; sometimes, but rarely, it is met with in limestone, and in that case is often found to give an asbestiform appearance to large masses of the rock, or the gangue that contains it. It occurs thus occasionally, as already mentioned, in a pasty state, and then hardens on exposure to the air. It is also found, in masses, in feldspathic and chloritic rocks.† One instance has been noted of its occurrence in quartz;‡ but here, when six feet of the rock had been blasted away, the inevitable serpentine was found cropping through. In the Coleraine and Black Lake district of the Eastern Townships of Canada, it is occasionally found in contact with granite, which is not held to be a good sign. For some as yet unexplained reason (although granite, like porphyry, is one of the richest metalliferous rocks), the granite seems to detrimentally affect the quality of the fibre. Granulite, on the other hand, as will be seen later on, has quite the contrary effect. At East Broughton, the asbestos

* "La Vie Souterraine," 406. † Davies on "Earthy and Other Minerals."

‡ James Boyd on "Italian Asbestos."

occurs along the contact between the serpentine and black Cambrian slates; and here, although the asbestos is remarkably good, there is a striking difference in its appearance. Another divergence is that of a case cited by the State mineralogist for California, where the asbestos vein occurs in a belt of slate enclosed in granite; but the asbestos here, like most of that found in California, is brittle and wanting in elasticity. Many specimens have been sent me for trial from this part of the world, but none of them have as yet been found to possess much commercial value. The enclosing rocks must, consequently, always claim the highest consideration of the explorer, because it is certain that, although some rocks are highly favourable to the formation of good fibre, others are just as much opposed to it. The serpentine, in which it generally occurs, is, in most cases, a product of the hydration of rocks containing olivine, augite, hornblende, and other intrusive or erupted igneous masses. It is essentially a hydrated silicate of magnesia, resulting from the alteration of magnesian rocks. Containing some protoxide of iron and other impurities, these frequently cause a change in colour from a dull green to brownish or reddish brown, often marked with red or purple. In olivine, under the action of carbonated waters, the iron is frequently carried off instead of being peroxidized, some of the magnesia being removed at the same time; hence comes serpentine, which frequently retains the crystalline form of chrysotile.

Most minerals, even when their general nature and component parts are very nearly identical, are found to vary very considerably in appearance and character, according to the different conditions of climate and locality; sometimes, even in adjacent localities, they will vary with the nature and surroundings of the rock in which they occur. Asbestos forms no exception to this rule. It is widely disseminated over the globe, but the deposits are not found to repeat themselves in different regions, even in strata of the same age, but both in appearance and composition will be found to vary very greatly. This difference may occasionally be caused by variation of

constituents, as in some of the South African varieties, but in others it may be the result of formation under different temperatures, or according to different rates of cooling.

To be of any economic value, the essentialities of asbestos are length and fineness of fibre, tensile strength and flexibility, combined with great power of fire resistance. Some of these qualities are often lacking, and the value of the mineral consequently diminished, even when it has the most promising outward appearance, as in that from Griqualand.

The main point in which asbestos differs from other minerals lies in its being both fibrous and textile. Subject to what is stated above, its quality is determined by the greater or less proportion of siliceous matter with which the fibre is associated. When crushed out from the rock, and freed from all harsh or gritty particles, its fibres vie in delicacy with silk, and, after carding, are spun and woven in precisely the same way. For a long time they obstinately resisted all attempts in this direction, the difficulty arising, as will be explained subsequently, from the peculiar formation of the fibre, which, possessing a perfectly smooth surface, and being much less elastic than fibres of organic origin, would seem of necessity to require the admixture of some foreign material to enable it to be spun into a yarn. That difficulty, however, has now been so entirely overcome, that yarns capable of withstanding great tensile stress can be readily produced by machines constructed for the purpose. The difficulty of twisting it into a thread becomes at once apparent when its behaviour in the breakers and carding engines is seen, and this difficulty will be more fully explained presently. Instead of leaving these in a sheet or "lap," it drops out in separate fragments just as it entered, except that the fibres are combed out straight and laid side by side parallel with each other. The carding is, however, ultimately accomplished in several successive machines, each set to a finer gauge than the preceding. The entire process consists of one long brushing and combing, in which cylinders, covered with teeth of gradually increasing fineness, pass the fibres from one to another, continually draw-

ing them out, until all the knots and irregularities are eliminated, and they lie straight and parallel.*

Regarding the general use of asbestos, Germany is a large consumer. In France the consumption is not so great, though some very good qualities of paper were some time ago made there. The industry is, however, apparently reviving in France, an energetic attempt having recently been made by a company, calling itself La Société Française des Amiantes, at Tarascon-sur-Rhône, for the production of the usual qualities of asbestos goods, accompanied by some others of a novel character. Paris was the first to set an example, by following out Aldini's idea of protecting firemen by a dress of asbestos cloth, which has since been followed up in London, after conclusive proof of its practical utility, in Paris.

But America is as far way ahead of any other country as a consumer of asbestos, as she is also in her manifold applications of it. A good deal is used in England in the manufacture of some valuable kinds of packing for engineering work, millboards, felts, lubricants, paint, and the like; but in England we lack in some degree the readiness which is found on the other side of the Atlantic, in the adaptation of new materials, and the adoption of new methods of working up those in use.

Whether it be that Englishmen are influenced by climatic or other causes, certain it is, that they are slow to adopt new systems, to cultivate novel ideas, or to move out of old grooves. Consequently, when new materials, or even novel applications of those long used, are suggested, they ponder over them, hesitate, and weigh the chances, and, in so doing, not infrequently let slip valuable opportunities; whilst the keener and more enterprising American, once he sees the drift of the new matter, will, to use his own expression, "catch hold" at once. It by no means follows, however, that in England this is the fault of the manufacturers alone; they have naturally to gauge the requirements of their customers, and prefer to limit their make to what they know they can sell.

* *Engineering*, 6th March, 1885.

CHAPTER II.

PRESENT SOURCES OF SUPPLY.

GENERAL RANGE OF DEPOSITS—Intermediate Varieties—United States —California—Russia—Siberia—The Ural—China—Africa—Blue Asbestos—Crocidolite—Natal—Barberton—Italy and Canada—Future supply.

As already mentioned, asbestos, in one form or another, and in more or less abundance, is pretty well diffused over the whole surface of the globe. It occurs in England, in Aberdeenshire in Scotland, and at Lough Foyle in the north of Ireland. It is not found in any great abundance in France; but is plentiful in Portugal, Spain, Italy, and Savoy. It occurs in profusion and singular purity in the Island of Corsica, where, however, the condition of land tenure forms an obstacle to working the deposits. It is found in Switzerland and in Germany; in the Pyrenees, and also in Greece, Turkey, Asia Minor, and Russia. It occurs also in Greenland and Iceland; in some parts of South America, notably in Brazil; in Australia, Tasmania, and New South Wales. In North America it is frequent, occasionally abundant, but often of a coarse character. In south Norway it is found in association with the apatite-bearing rocks; in other parts of Scandinavia it mostly takes the form of mountain wood or cork.

Specimens from all these places are to be found in England, in the museums, or preserved as curiosities in private collections; but, in by far the larger number of cases, their brittleness, coarseness, or want of flexibility deprive them, for present purposes, of any commercial value. In many localities

where the quality is good, the quantity available is not sufficiently abundant to pay for working. The seams vary very greatly in different regions, not only in length of fibre, colour, and general appearance; but whilst they have, almost universally, the same dip and inclination, they differ very greatly in composition.

The intermediate varieties, the produce of different lands, are many of them not only singular, but, in some cases, singularly beautiful. The asbestos of different countries is as varied as the characteristic foliage. What, for instance, can be more strange than the bluish aspect of the Australian trees, compared with the soft, delicious greens of the English foliage, when luxuriating in the moist, but clear, atmosphere of early summer? And how different this from the gorgeous hues of the Canadian maple, which can be likened to nothing but a succession of gigantic bouquets of tropical flowers, often thrown prominently into relief, by a deep background of pine—a never-ending source of delight to the traveller! Then contrast the smooth and white, rock-like, form of asbestos from the Pyrenees with the harsh and brittle tremolite of Servia, unpleasant to handle, its fine needle points insidiously penetrating the skin, just like the particles of slag wool; and compare this with the long, soft silkiness of the Corsican variety, the hanks of which look like skeins newly wound from a cocoon, the resemblance being all the more perfect from some of these being a silvery white, whilst others are of a pale gold colour; then turn, again, to the singular Scandinavian forms, which are rough and rugged as the country from which they come.

That asbestos of good quality is not found in the United States, in workable quantities, is shown by the fact that, whilst America is by far the largest consumer of the mineral, her supplies of crude ore are almost entirely derived from Canada. Out of a total export from the Dominion of 3,936 tons in 1888, no less than 3,612 tons were taken by America. It may certainly be that some portion of this large quantity was bought by dealers in New York, who afterwards exported

it at enhanced prices; but of this we have no data. In 1889, under the stimulus of the high prices then ruling, the exportation from Canada was much larger; but for that year the proportion of the amount exported will work out very differently, as four of the mines have been purchased, and are now worked, by English and German manufacturers, who require the whole produce for their own special use; the output of these mines, therefore, is practically withdrawn from the market.

But even if it could be said that the quality of the ore found in America was good, the deficiency in quantity is shown by the official returns. According to these, the total production of asbestos in the United States for 1888 * is stated to have been 150 tons only, the value of which is put at about £6 per ton, which sufficiently indicates the quality. Moreover, the figures for recent years show a continual falling off in production in precise accord with the rise in price of Canadian, which can only be attributed to the growing appreciation of the merits of Canadian ore for manufacturing purposes.

In 1882 the produce was returned at			1,200	tons, valued at	$36,000	=£7,422
,, 1883	,,	,,	1,000	,, ,,	30,000	6,185
,, 1884	,,	,,	1,000	,, ,,	30,000	6,185
,, 1885	it fell to		300	,, ,,	9,000	1,855
,, 1886	,,		200	,, ,,	6,000	1,237
,, 1887	,,		100	,, ,,	4,000	824

whilst, as we have already seen, in 1888 it was 150 tons, valued, like the foregoing, at little over £6 per ton. This shows clearly enough that American manufacturers do not rely on home production, and as they make no use of Italian ore, their dependence at present is necessarily on that of Canada to meet their rapidly increasing requirements. Probably the official returns refer to amianthus alone, under the head of asbestos, because it is well known that large quantities of a coarsely fibrous mineral (talc or tremolite) are used in New York, for instance, and also exported thence to England, and of course

* "Mineral Resources of the United States for 1888."

under the pressure of the high prices now ruling the production and sale of this form, under whatever heading it may be classed, will be largely increased.

In 1887, there was a good display, of the economic minerals of the United States, on exhibition at Earl's Court, Kensington; but my journey thither was fruitless, so far as asbestos was concerned, there being, in the whole collection, but one small tray of amphibole,* and even that was of no commercial value.

In California, that rich storehouse of the economic minerals, asbestos occurs in many places, and sometimes in deposits of considerable extent, but out of numerous samples forwarded from that state, none have yet been found that, with our present limited knowledge of the capabilities of the mineral, would pay for working. In San Diego County, asbestos of a coarsely fibrous kind occurs in a belt of slate enclosed in granite, an unusual formation. Here the strike is north 70° west magnetic, and the dip nearly vertical; the ore is exposed in an open cut 15 to 20 feet long by 6 or 8 deep. There are deposits also in Placerville, El Dorado, and Lake Counties. Some of them possess sufficiently good fire-resisting qualities, but they are mostly deficient in tenacity. It is not to be said that these forms are worthless—their value will no doubt presently be discovered—but at this moment, when the practical uses of the mineral are so far undeveloped, it is only the more silky fibres that are in special demand. For grinding, the manufacture of cement, boiler and pipe coverings, roofing materials, and similar purposes these Californian varieties may be useful; but generally the supply of refractory minerals for use in this way is sufficient to meet the demand.

In Wyoming considerable deposits have been discovered but these are all of a coarse character, and although it is reported that a good deal has found a market it does not appear to be of much value, though somewhat different in character from the foregoing.

* "On attribue généralement à l'amphibole les mineraux fibreux, et plus ou moins flexibles, que l'on a désigné sous le nom d'asbeste ou d'amiante." —Jagnaux, 550.

Writing on undeveloped substances in 1876, before the introduction of Canadian asbestos, Mr. Simmonds, editor of the "Journal of Applied Science," remarked, that an examination of the several varieties of asbestos (from America) appeared to indicate a gradual increase in the tenacity of the fibre found in a direction proceeding from Georgia to Vermont, where the quality appeared to culminate in the asbestos found in the northern part of that state. Now, we know that, passing over the border, from Vermont into the Eastern Townships of the province of Quebec, the fibre is found in the highest state of purity and perfection in the great belt of serpentine traversing those townships, especially in Wolfe, Megantic, and Beauce.

Asbestos occurs abundantly in various parts of Russia, especially in Siberia and the Ural, but up to the present time little use has been made of it there, on account of the prevailing ignorance respecting its peculiar properties. An amusing instance of this occurred some time ago at some iron works in the interior with which I was at the time connected.

The iron ore, in the district referred to, is found in bunches and nodules, near the surface of the ground; and in order to get it, the peasants dig out pits about seven or eight feet in depth, and then burrow, rabbit-like, into the surrounding earth in all directions below. When all the ore is got out from one spot, they dig another pit further afield, and so they go on until the particular patch of ground they are working on is exhausted. On the occasion referred to, some of our men, in their burrowing, threw out a considerable quantity of asbestos. They had not the slightest idea what it was. In fact, they knew nothing at all about it, except that it was not what they were in search of; and, consequently, as it obstructed their work, they threw it all out in a heap, near the piles of ore. Presently, one of the foremen or overlookers saw it, and wanted to know what that rubbish had been put there for. "Here," said he, to some of the men, "just clear up all that mess at once, and fling it into the furnace, and get rid of it." And this was immediately done, with what result may be easily imagined.

At the present time, St. Petersburg possesses the only manufactory for the use of asbestos in Russia, but probably the time is now ripe for a change. Recent information has been received, of the discovery of enormous deposits of the mineral, in one or two places, which, it is said, as usual in these cases, are of the finest quality. Its value commercially will be dependent, first, on the quality, and then on the nearness of the mines to an available market, transport being necessarily an important factor in the element of cost. But as a matter of fact, the specimens of the mineral sent from Russia hitherto, have not been up to the mark. There is some reason, however, for believing that the new discoveries are of a different character from those previously made.

Siberia, being so well known for its rich mineral treasures, and the formation of some parts of the country giving indications of the whereabouts of asbestos, the recent discoveries there are by no means surprising. It seems, moreover, that the inhabitants are now realising the value of the discovery, for the protectionist papers are clamouring for the imposition of a prohibitive duty on imported asbestos, so as to encourage local industry. For many reasons, not the least of which is difficulty of communication, the rich mineral treasures of Siberia have not yet attracted much attention from European capitalists. This important question of communication is, however, now being gradually overcome, and means of establishing a trade will soon be found by the German merchants who overrun the country in every direction.

Some little while ago the Technical Society of Moscow announced the fact of its having received some unusually fine specimens of asbestos from Ekaterinburg, accompanied by scientific reports which seem clearly to establish the existence of large deposits of the mineral. From Orenberg to Ekaterinburg the whole country is reported to be traversed by rocks containing deposits, culminating near the Verkin Tagil Ironworks, in the vicinity of which is a hill called by the peasants Sholkovaya Gora (hill of silk), which is said to be entirely composed of asbestos. The principal of these deposits lie

close to the railway, the facilities afforded by which, aided by those of the Volga River system, will materially assist in opening up an export trade, as soon as these deposits are properly worked. Further deposits have also been disclosed in the Gorobtagsdat and the Neujansk districts of Perm. Similar announcements were, some short time back, made of discoveries in South Russia, but the local excitement died away when it was found that the quality was not as represented.

Asbestos has been found in Alaska, but, there also, difficulty of communication blocks the way.

Chrysotile has been found at Ilfracombe in Tasmania, in Australia, and New South Wales. Asbestos in long, white, silky fibres, occurs at Jones Creek, Gundagai, where fine specimens of pyrophyllite are found; with meerschaum at Bingera, Murchison County, and picrolite is found at Kelly's Creek, Gwydir River. Jagnaux gives the following analysis:—

Silice	55·19
Magnesie	31·58
Chaux	—
Oxide ferreux	1·70
,, manganeux	—
Alumine	1·40
Eau	10·62
	100·49

The value of the asbestos raised in 1885 and preceding years, however, amounted only to £3,216. The serpentines in Australia, as elsewhere, in which the asbestos is found, are in close association with deposits of chrome iron and other minerals.* Those with which the asbestos deposits are most commonly associated are soapstone, magnetic or chromic iron, and occasionally mica and enstatite; chromite is less frequently met with, but generally all iron found in the workings is called by the miners chromic. The colour of Australian asbestos is usually white or a light dingy blue, the form densely

* "Minerals of New South Wales," by A. Liversedge, F.R.S., 1888, p. 180.

compact, but the fibres easily separable. The Native Asbestos Company is located in Flinders Street, Melbourne, Victoria.

In China also asbestos occurs; but, apart from the manufacture of a coarse kind of cloth, we know little of any purpose to which it is there applied. One singular use of it may, however, be mentioned, which Dr. Hobson, of the London Medical Mission, brings to our notice. He says that it is used by the Chinese as a medicine and figures, in their pharmacopœia, in company with such uncanny things as "dried spotted lizard, silkworm moth, human milk, the parasite of the mulberry tree, asses' glue," &c.; and, this being so, we are quite prepared to take Cobbold* at his word when he tells us that the native practice of medicine in China is not easy for a foreigner to understand. Before, however, we smile, or turn with disgust from the medical practice of the "heathen Chinee," it will be well to call to mind, that it is less than 200 years ago since such horrible things as "toads, vipers, centipedes and worms, found a place in the official pharmacopœia of the London College of Physicians."† Hippocrates prescribed asbestos as a cathartic, but it is probable that under this name he referred to native carbonate of magnesia.

Now if we turn to Africa, "the land of sparkling gems," which, in all ages, has been celebrated for its mineral wealth, and which now, as in the days of Aristotle, "has always something new to show," we shall find her true to her reputation and showing several new, or rather unfamiliar, varieties of asbestos. Africa has (perhaps in some moment of despondency) been stigmatised as "a country of samples," but when we remember that she has furnished the world with *six tons* weight of diamonds, a thousand tons of ostrich feathers,‡ with gold, and other produce, in equally fabulous quantity, it must be admitted that her samples are of rather a portentous character. And even now, whilst her wealth of gold and gems is being distributed in such lavish abundance, news is flashed

* "Pictures of the Chinese Painted by Themselves."

† "English Folk Lore," by the Rev. F. T. Thiselton Dyer.

‡ "The Land of Gold, Diamonds, and Ivory," by J. F. Ingram, F.R.G.S.

home that she again "has something new to show," asbestos having been discovered, according to report, of a quality and in such abundance, as has never before been seen.

Crocidolite (blue asbestos) has long been known to exist in the neighbourhood of the Great Orange River; both crocidolite and soapstone were among the mineralogical specimens brought home, from the Kalahari Desert, by Mr. Farini; and a special variety of asbestos, of a highly aluminous character, occurs in Natal.* This last is imported into England for use in the potteries as a refractory material for lining furnaces and kilns, and for the making of crucibles, for which it seems to be well adapted, alumina being both insoluble and infusible.† Asbestos is also found in abundance in the Somali fields, about a hundred miles beyond Kimberley; and yet another discovery was announced in September, 1889, of a "gigantic asbestos farm," (whatever such an expression may be taken to mean), on the property of the Griqualand West Copper and Mineral Syndicate. The find here was, with the usual exultation, announced to be amianthus of the finest quality, beautifully white in colour, and many feet in length. The first samples sent over, however, by no means bore out this description, being comparatively short and brittle. The produce of deeper workings soon followed; some of these in my possession are very beautiful in appearance, in fineness of colour and length of fibre not to be surpassed by the best Italian, but, at the same time, they are so deficient in tensile strength as to be practically useless for any present purpose. But although for

* Alum is often found efflorescent or in feathery masses; and in many parts of Africa, notably at Lagoa Bay, it occurs in fine crystallisations like asbestos with a silky lustre; in a cave near the Bosjesmans River it is said to cover the floor to a depth of six inches. Sapphire is pure alumina crystallised; but the sapphire of the ancients was lapis lazuli, as appears from Isidorus: "Sapphirus cœruleus est cum purpura, habens pulveres aureos sparsos," particles of iron pyrites disseminated through it and looking like gold.

† "The magnesian silicates are only fusible at very high temperatures, but the silicates of alumina are probably quite infusible."—Pickett's "Useful Metals and their Alloys," 624. *Vide post*, 169.

this particular kind there is no demand now, it must not be forgotten, that every year brings to light new mineral combinations, or new varieties of those with which we are already acquainted, and usually the practical application of them soon follows.

When these African discoveries were first announced, simultaneously with those in Russia, and those anticipated, with less probability of realisation, from Servia, fears were expressed lest the markets would be glutted and prices so reduced, as to make it scarcely worth while to work the mines, but it must not be forgotten that

> "Le globe est un vaisseau frété pour l'avenir
> Et richement chargé . . . . ,"

and that as new scientific discoveries are made, so the great mineral reserves which, year after year, are brought to light, readily find their place, without much disturbance, in the great economical relations of the world.

The important question of transport, from these distant regions, will be one of the first difficulties to present itself; but granted a practical acquaintance with the mineral, no great difficulty need be apprehended on this head.

Bearing in mind the great number of places, in the neighbourhood of the gold mines, where both asbestos and crocidolite abound, it would not appear at all unlikely that, in the near future, a good quality of asbestos will be discovered, and that Africa may become one of the main sources of supply. The elevation of Griqualand West is about 4,000 feet above the sea level, a not unimportant factor in the case.

In addition to the African localities already indicated as the whereabouts of the mineral, travellers seem to have been frequently on the verge of discovery. Anderson * found in the Kuruman range, at Blaaw Klip, a soft stone, which the natives dug out from the hillside and formed into pipes, plates, &c., no doubt a kind of ollite, or potstone, which would seem to indicate a promising locality for asbestos. And

* "Twenty-five Years in a Wagon," vol. 1.

Dr. J. W. Matthews, * who spent a considerable time in that region, reports that the calcite, which runs through the blue ground in all directions in the diamond district, was covered with a coating of a "greyish-white substance, very soapy to the touch, and resembling steatite."

The importance of the subject, in view of the probability of the South African asbestos mines coming prominently to the front at an early date, will perhaps justify the insertion here of an extract from Dr. Schenk's report on the formation at Barberton. The Doctor, an eminent geologist, who has paid several visits to the goldfields, says that the formation there consists of very old, and, in most instances, highly metamorphosed rocks, composed of slate and sandstone, with interposed eruptive rocks of greenstone (diorite, serpentine, &c.). These rocks are highly erected, dipping invariably at great angles, often perpendicular, and run from east to west. It is in this formation that the gold-bearing reefs are situated, and these, with few exceptions, run in the same direction, nearly always accompanying the eruptive rocks. The gold, in his opinion, came with the eruptive rocks from the interior of the earth to the surface, and there became concentrated in reefs, which consist of quartz, and often contain iron with the gold. There is no young formation overlying these rocks at Barberton but, in the Drakensburg and Witwatersrand, a younger formation lies unconformably over the older rocks, which he concludes to be of Devonian age. The younger formation has subsequently been folded in the same way as the Barberton rocks, though it is not so highly erected. †

In a country where the hitherto usually recognised features of the mineral seem to be so diversified in colour, texture, and component parts, we should not, perhaps, be surprised at any further distinctive feature; yet it seems somewhat strange to be told of an "asbestos farm"; and, again, to find it stated, on the authority of "an eminent engineer, late Surveyor of Lands to the German Government," that on part of the ground

* "Ingwadi Yami," 148. † "Ingwadi Yami," Appendix.

where some of the new discoveries have been made he traced four distinct "*asbestos reefs*, three feet wide, and running parallel to each other at regular distances for many miles," * a description calculated to make an asbestos expert open his eyes in wonderment.

Crocidolite in its earthy form occurs abundantly in the same region, varying in colour according to the mineral oxide which may happen to be present. Much of it is of the kind called "Tiger-eye," from its tawny-coloured, streaky brilliancy. It is of a densely compact nature, from its exceeding hardness difficult to work, but susceptible of high polish. The grain is very fine, and, even in the rough state, the fibres are singularly distinct. Some other minerals possess this peculiar shining lustre, though none in so fine a degree. Cat's-eye (Katzenauge), for instance, a chalcedonic quartz, when cut *en cabochon*, exhibits a like opalescence, or glaring internal reflection, like the pupil of a cat's eye, which is caused by the fibres of asbestos running through it. The same peculiarity, but in a lesser degree, is sometimes found in satin spar, when cut in the same way.

Chrysotile has been found on the Stewart River, British Columbia, where the occurrence of large masses of serpentine tends to justify the expectation that workable deposits will presently be found. †

In the district of Lake Temagami, to the north of Lake Nipissing, asbestos has been found from half an inch to nine inches long. One of the veins here shows about a foot wide, running in trap in the same direction as the quartz.‡

Although the statement with which this chapter opened that asbestos, in one form or another, is found in most parts of the world, has now been substantiated, Italy and Canada, which at present constitute the chief sources of supply, remain to be

* *The Diamond Fields Advertiser*, quoted in the *Weekly Bulletin*, September 7th, 1889.

† Report on the Yukon District, N.W.T., by G. M. Dawson, 1888.

‡ Report of the Royal Commission on the Mineral Resources of Ontario, 1890, p. 57.

considered; but so distinct and so important are the productions of these two countries that they need to be separately dealt with.

As to the more immediate outlook, it must be remembered that although, for their own special productions, these two countries are, for the present, the undoubted masters of the field, it is scarcely probable, in view of what is now taking place in many other parts of the world, that they will permanently remain so. So far as Italian produce is concerned, the company, which practically monopolises this, requires all the asbestos it can get for its own use, and in order to supplement the produce of its Italian mines, has recently bought a mine in Canada, and there also it will, in future, be a producer as well as a consumer. Indeed, the large consumers of the Canadian mineral, feeling the pinch of continually increasing prices (in consequence of supply not keeping pace with demand), are gradually buying up all the present best-known mines and turning miners themselves, the natural effect of which is that the produce of the mines so bought is withdrawn from the general market. It therefore becomes increasingly difficult for those consumers who are not also mine owners to obtain the supplies they want. A natural consequence of this state of things is further increased price and greater exertions to find fresh sources of supply. It is only, therefore, to be expected that new discoveries will continue to be made, and it may turn out that Italy and Canada will presently find both Russia and Africa formidable competitors. Dealings with the former country may, from many causes, remain somewhat difficult for the present, but with Africa the case is different. Given the requisite quality, the question of transport will soon be overcome, and it is only fair to assume, from what we have seen, that the right quality will presently be found there, and when that is the case, if the mines are only intelligently handled, methods, which almost indicate themselves, will speedily be adopted to settle the transport question.

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ITALIAN ASBESTOS. "THE FLOSSY."

CHAPTER III.

ITALIAN ASBESTOS AND THE ITALIAN MINES.

ITALIAN ORE a Distinct Variety—Essential Characteristics—Mr. J. Boyd's Paper—Italian Exhibition—Quantitative Analysis—The Mines—Varieties of Ore—The United Asbestos Company and its Operations—The Industry as carried on in France—The New Asbestos Company.

IN the modern use of asbestos in practical mechanics and the industrial arts, Italy ranks first in order of time; it is only fitting, therefore, that the produce of the Italian mines should be first considered.

Asbestos, as found in the Italian hills, differs materially in appearance, form, and character from the mineral, so called, which is found in Canada: but the intrinsic features of the two kinds are practically the same, and the uses to which they are put are nearly identical.

It would serve no useful purpose now to revive the vexed question of their relative merits; practical experience in their use has shown that both possess undeniably good qualities, and that there is ample demand for both; those very qualities, in fact, which may render one of them less suitable for some particular purpose being precisely those which best adapt it for another.

Some fine specimens of Italian asbestos are occasionally to be seen in London, at the various exhibitions. One of the exhibits at the recent Italian Exhibition at South Kensington, of an unusual character, was described in the catalogue as a "Collezione d'amianti italiani in 70 vasetti"; these were sent from Rome by the "Impresa mineraria italiana" of that city, which company has an office in Leadenhall Street, London. Many of this large

number of specimens were curious both in structure and colour; but it must not be supposed that they were so many distinct varieties; indeed, except as curiosities, their exhibition could scarcely be said to answer any specially useful purpose, as there were no analyses given, nor any facilities for their examination by experts.

In examining such a mineral as asbestos with a view to determining its economic value, too much importance cannot be given to its quantitative analysis. It is evident, however, that, when dealing with asbestos, accurate agreement between any two operations must not be looked for, unless the samples analysed are not only from the same mine, but from the same part of the same mine; because, though the constituents may be the same, the proportions may be different. In comparing, therefore, any two or more analyses made by different individuals, these can only be expected to agree approximately, unless we knew that they were the results obtained from analysing parts of the same piece of ore. To be of any commercial value, asbestos needs length and fineness of fibre combined with infusibility, toughness, and flexibility; some of these qualities are often wanting in a mineral of a very promising appearance. The qualities of length and silkiness can, of course, be determined by the eye, but why a beautiful silky specimen, such as some of those from South Africa, should be wanting in such essentialities as infusibility, tenacity, or elasticity, can only be determined by an accurate knowledge of the proportions of its constituent parts.

A consideration of this point will no doubt be sufficient to excuse the insertion here of one or two analyses, made by different gentlemen, all of them of sufficient eminence to justify the insertion of their work for comparative examination.

The first is taken from a very interesting paper * on Italian Asbestos, read before the Society of Arts in April, 1886, by Mr. James Boyd, from which paper the description of the Italian mines here given is mainly derived. In this paper the following comparative analyses of the Italian and Canadian

* *Jour. Soc. Arts*, No. 1743.

minerals are given, that of the Italian having been made by Prof. Barff.

	Italian.	Canadian.
Lime and magnesia	37·84	33·20
Silica	41·69	40·90
Oxide of iron	3·01	5·75
Potash	·85	traces
Soda	1·41	·68
Alumina	2·57	6·60
Moisture evaporated at 100 C.	3·04	—
Loss on heating to white heat, water of hydration, and organic matter	9·56	12·50
Chlorine	—	·25
Loss	·03	·12
	100·00	100·00

The professor, in a note appended to his analysis, remarks: "This asbestos contains nothing injurious to metal with which it comes in contact when used in connection with machinery, and the special character of Italian asbestos renders it vastly superior to that found in Canada." The first part of this sentence is just as applicable to Canadian as to Italian asbestos, but the concluding part is somewhat puzzling, as the professor does not tell us what the special characteristics he alludes to are, and they do not appear to indicate themselves by a comparison of the figures. Soon after the publication of this I had an opportunity of getting a sample of each sort analysed in Italy, through a friend there, the results of which were as follows:—

	Italian.	Canadian.
Magnesia	40·15	33·21
Protoxido de ferro	·75	5·77
Alumina	2·82	6·69
Silica	40·25	40·90
Acqua de hydrato	14·20	12·20
Soda	1·37	·69
Potassia	indicios	indicios
Cal.	,,	,,
Chlorina	·51	·22
Acido sulphurico	·31	indicios
	100·36	99·68

In regard to these the analyst remarks: "Although the Canadian sample shows a less percentage of magnesia, the difference is fully compensated for by the larger quantity of protoxide of iron and alumina."

The comparative analyses of the two ores which follow recently appeared in one of the American scientific journals, and were stated to have been made by Professor Durst, who has made a special study of the subject; and the concluding analysis of Canadian ore is one made by Mr. Donald, Professor of Chemistry at the McGill College, Montreal:

	Italian.	Canadian.	Canadian.
Silica	40·25	40·92	39·05
Magnesia . . .	40·18	33·21	40·07
Water of hydration .	14·02	12·22	14·48
Alumina . . .	2·82	6·69	3·69
Protoxide of iron .	0·75	5·77	(oxide) 2·41
Soda	1·37	·68	—
Potash, &c. . .	·15	·22	—
Sulphuric acid . .	·31	traces	—
		Undetermined	·30
	99·85	99·71	100·00

Professor Durst expresses his opinion of the result of his work in this way: "Thus, while the Italian possesses a larger percentage of magnesia, it is poorer in alumina, and holds more water than Canadian. The Italian, obtained in long fibres, sometimes reaching 3 feet, cannot be worked with the same ease and evenness as the Canadian. The product likewise is not so uniform, while its greater density and weight renders it less desirable and more expensive for general use."

It seems clear, however, that, making all due allowance for difference of locality and surroundings in the samples analysed, the analyses are for all practical trade purposes in sufficient accord, whilst the balance of evidence is against Dr. Barff, both in precision of statement and in agreement with general commercial opinion.

The statement of Professor Durst, as to the superior ease with which Canadian fibre can be worked, seems to be cor-

roborated by the following extract from a Canadian technical journal. Few people have had more practical experience, or can speak with greater authority than Mr. Boyd.

"Mr. James Boyd, managing director of the British Asbestos Company, writes to the London papers respecting the New Asbestos Company which has been formed to develop certain French and Italian properties as follows: 'I have recently heard that a Canadian asbestos property has been acquired by the Company holding the greater part of the Italian properties, or by parties interested in it. They could raise hundreds of tons from their Italian properties; and if they do not do so there must be a reason for it, and I believe the reason may be sought for in the fact that, whilst Canadian asbestos fibre can easily be spun into thread fit for manufacturing into rope or cloth, Italian can only be so spun on a commercial scale by the admixture of cotton, or some other material, owing to the want of cohesion amongst its fibres. Owing to the increasing steam pressures used in connection with triple expansion engines, a great increase has taken place in the consumption of packings made of asbestos cloth, and I believe it is practically impossible to make this of pure Italian asbestos. The English Admiralty have, I believe, persistently refused to put Italian asbestos packing on their list, for the reasons above stated. . . . The protective tariffs, so called, in France are not so high as to prevent both Italian and also English manufacturers of Canadian asbestos goods from selling their manufactures there; and as a matter of fact, the prices in France are lower than in England.'"*

The statements in the foregoing extract are singularly corroborated by the fact that the company first named, the "Impresa Mineraria Italiana," are now almost exclusively devoting their attention to the manufacture of various grades of asbestos cloth, which they make from the Canadian mineral alone.

There are three principal varieties of asbestos found in Italy, the grey, the flossy, and the silky. There is also an-

* *The Canadian Mining Review*, March, 1890.

other of a powdery character, of which a good deal is used, but to which not so much importance is attached.

The Grey variety, of which an illustration is given, is a rough-looking saponaceous fibre, of great tenacity and of considerable length. This is often found high up in the rocky face of the mountain, but occasionally on a lower level in the Alpine valleys. Sometimes it occurs in such difficult positions that, in the first stages of the work, the men have to be let down by ropes from above to bore the holes for making a working platform. The high table-land of Acqua Nera, 6,000 feet above the level of the sea, has its whole western face composed of rocks rich in asbestos, the seams of which run in a nearly vertical direction.

The Flossy form is dry, with a smooth silky fibre. This occurs generally in thick horizontal seams, which have a rapid dip when once the rock is opened. A large quantity of powdery material is found with it, in the centre of which lumps of quartz, and substances apparently of vegetable origin, are occasionally found.

The Silky variety is much like the flossy, but has a smoother texture, is longer in the fibre, and of greater tenacity. This is the kind mostly in use for gas-stove work.

The Powdery is found in the same range of mountains as the flossy, but generally at a much lower level. Like much of the mineral found in various parts of the world, it exhibits a pasty appearance when first opened up, but it rapidly dries and pulverises on exposure to the atmosphere. The Société Française des Amiantes claims that this powdery material is of great value to agriculturists as a manure, and to viticulturists for application to the vine stocks as a preventive of mildew and a destroyer of the phylloxera. It has been tried in England, with a similar object in view, in the hop gardens of Kent, but with no marked success; indeed, it is somewhat difficult to understand what there is in its composition to give it any efficacy for either of the purposes named.

Italian asbestos is rarely found at a lower level than 5,000 feet, ranging from this upwards to 12,000; in fact, up to the

line of perpetual snow. It is usually got by running driftways into the face of the rock, when the seams, on being followed up, often abruptly end in pockets, which sometimes contain as much as a ton or a ton and a half of asbestos. When first taken out from the rock the ore is in lumps, forming hard, closely compacted, bundles of fibres, varying in colour from light grey to a dingy brown. With a little care threads of many feet in length may be drawn out from these bundles, the fibre closely resembling flax, but in appearance only, the difference being quickly perceptible to the touch.

In searching for asbestos on the Italian hills, the prospector is not guided by the same rules as those which guide the explorer in Canada; he looks in the perpendicular face of the rock for cracks, which may be filled with a white powdery substance which, when the surface is broken away, soon assumes a leathery appearance, and then, when further entry is made, the true asbestos is found. Mining for asbestos in Italy is, as a rule, carried on with greater difficulty than in Canada, and the supply of the mineral, if more abundant, is much more uncertain.

Mine owners in Italy, desirous of effecting a speedy sale of their property are, it is to be presumed, no better or worse than others in the same position elsewhere, in being apparently not averse to the practice of "salting." In Italy this salting process seems to consist in driving fine asbestos fibre into the crevices of the rock, and then, so far as possible, giving it the appearance of the real formation. Mr. Boyd tells us that in one instance of the kind which came under his notice, a sum of about £200 was actually paid for the right of extracting asbestos from the barren rock which had been so treated. Here, at any rate, the asbestos did not follow the usual course by running into a pocket, whatever might have been the case with the money.

Mr. Boyd, in the paper previously referred to, makes a statement of a very suggestive character as the result of long observation in Italy, which is worth recording. He says that "if asbestos be found on the surface of a rock exposed

either to the south or south-west, the product is generally fairly abundant and of good quality. If exposed to the east there is fine quality, but very small quantity; whilst if exposed to the north the quantity is plentiful, but dry and hard, and on entering the rock all traces of it are lost."

Whether this be at all consistent with Canadian experience I cannot say. The lie of the ground and the course of the veins being so different, it is quite possible the theory may have no applicability at all to Canadian mining, but it is certainly worth the consideration of asbestos miners in other parts of the world, as well as in Canada.

Asbestos, as already explained, wherever it occurs, whether in Italy or any other part of the world, is found associated with other minerals, but occasionally, in the Italian deposits, minute crystals of a green-coloured garnet are found with the asbestos, which the miners call asbestos seeds (semenze dell' amianto).

It is now nearly twenty years ago since asbestos first began to be talked about in England, and attempts were very soon afterwards made to turn its peculiar properties to useful account. The time was getting ripe for such a business. Steam pressures had, for some time, been gradually rising. Although 30 lbs. to the square inch at sea, and 50 lbs. on land had hitherto been the average, these pressures were then beginning to be doubled, and consequently the old forms of packing for joints and glands were, under these new conditions, found to be incapable of withstanding the strain put upon them. Gasket rings and hemp gland packings had both to be superseded by more durable appliances, yet these were so far from being perfect that it was felt to be certain trouble would occur with them when exposed to the higher temperatures which were evidently coming.* Just about the same time asbestos millboard was being successfully made in Florence, and a good piston packing was made in America. Directly afterwards, a "Patent Asbestos Manufacturing Company" was established in Glasgow, for making piston packings after this American

* *Engineering*, March, 1885.

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ITALIAN FIBRE. "THE SILKY."

invention, and millboard after the Italian method. The peculiarity of the packing introduced by this Scotch company consisted in its being formed of a core of asbestos fibre, consolidated by machinery, and braided over with cotton to keep it together; and although this first attempt was somewhat crude, some wonderfully good results were obtained from it.

In 1879, one year after the opening of the first chrysotile mine in Canada, three firms which had made asbestos mining in Italy and the manufacture of asbestos goods a speciality, became amalgamated, as "The United Asbestos Company, Limited," of London; and this new company, having secured about 180 mining properties, covering 80 square miles, in the region of the Italian Alps, being nearly all the Italian mines then known, thereby at once, for the time being, obtained a practical monopoly of the trade.

The operations carried on by this company may be concisely stated as follows:—The crude asbestos, when extracted at the mines, is packed up in bags containing from one to two hundredweight each, and these bags are brought over to England, and discharged into lighters in the Thames, whence they are conveyed, by way of the Grand Junction Canal, to the company's works, at Harefield, in Hertfordshire. Here the bags, on being opened, are found to contain the asbestos in rough lumps, from the size of a man's hand to about as much as one man can lift. A sample of this crude ore can be seen at the company's offices, a remarkably fine specimen of the grey variety, brought from one of the company's mines in the Valtellina Valley.* This is a natural curiosity, and probably the finest piece of Italian asbestos yet seen.

When turned out of the bags the crude asbestos is, first of all, opened out by special machinery, constructed for the purpose, with the double object of loosening the fibres, and freeing these from the material by which they are compactly bound together. This is an operation which has no counterpart in the method of dealing with Canadian ore; nor for the

* A fine quality of alabaster (gypsum) is also found in this valley, so delicate as almost to resemble white wax.

Italian ore would any such opening machine as is in use in the shoddy or cotton waste trades do, as no tearing or cutting action can be permitted. Three machines, of gradually reduced sizes, are employed to open the asbestos, and then those portions which contain the longest fibres are taken to the boiling tanks, where they are rendered soft by heat and moisture. These tanks are each provided with a rotating beater, which maintains a thorough circulation, by first taking up the fibre, then opening and drawing it out, and afterwards sending it on to be soaked, until it comes round again to the beater. The short fibre, reduced to fluff, is taken to edge-runners and ground and prepared for the beating engines, where the binding material is added, and the whole thoroughly incorporated, after which it is drawn off into a receiving-tank, placed in the millboard machine-room. From this tank it is conveyed to the millboard machine, to which agitators are attached, to keep the fibre from settling. The water is drawn off through a fine wire gauze on a revolving cylinder, leaving a thin coating of the asbestos pulp on the cylinder. This is then taken off by an endless band, and transferred to a second solid rotating cylinder, where it steadily accumulates until the desired thickness has been reached. It is finally cut across, and removed in the form of a square sheet of millboard or paper.

This is much the same method as that adopted in France. Describing the mode of preparing millboard and paper there, Jagnaux says :—"Quant aux fils les plus courts, et ceux qui rest en pelotes on en fait de la bourre. C'est cette bourre qui, agglomérée au moyen d'un colle végétale, sert à la fabrication du papier et du carton d'amiante."

When the sheets leave the machine they contain a good deal of water, which is got rid of partly by pressure and in part by drying. They are then put between zinc plates and subjected to a powerful hydraulic press, which expels most of the remaining water, after which they are hung up, by spring clips in a steam-heated room, to complete the drying process, when, once more, the sheets are subjected to pressure, to

flatten them out and improve the surface, after which the edges are trimmed and the manufacture is complete. When trimmed, the sheets usually measure 40in. × 40, their thickness varying by thirty-seconds from $\frac{1}{32}$in. to $\frac{1}{4}$. The board is then cut up into shapes and sizes suitable for the special purpose for which it is intended. It is mostly used for making joints not exposed to the action of moisture, such as dry steam, air, or gas.

The step from millboard $\frac{1}{8}$-$\frac{1}{4}$in. thick to paper is so small, that many attempts have been made to produce an asbestos writing paper, which, from its indestructibility, would be invaluable in case of fire, for preserving charters, policies, agreements, and other important documents. Such a paper is made, but generally it is too uneven in texture, and too much akin to blotting paper to permit of its use as a writing paper.

The other great division of the manufacture, consists of such articles as require the production of yarns. To the initial difficulty of this manufacture we have already alluded. When yarn is wanted, the raw material is discharged from the boiling tanks into hydro-extractors, where most of the water is thrown out, the drying process being afterwards completed by steam heat. The fibre is then passed through a shaking machine, which separates the long fibre from the short, the latter being sent to the millboard department, whilst the former is reserved for the carding-room, where it has to pass through several processes before the manufacture is complete.

Asbestos cloth is woven in a loom exactly like calico, except that the reeds and healds are much coarser. The narrow cloth or tape is woven in a smallware loom. Both the sheeting and the tape are used for making joints, and the former is sometimes rubber-proofed to render it water-tight. The asbestos and india-rubber woven tape is so constructed that it can be bent round a corner without puckering, and thus is particularly useful in making joints in manhole and mudhole doors. If the cloth or tape be rubbed with plumbago or powdered asbestos before it is used, the joint may be broken and re-made many times with the same packing. The cloth is

also worked up into square gland packing, by being cut into strips and built into a square rope, with a backing of pure rubber to give additional elasticity. The edges of the strips lie in contact with the rod, and as the gland is screwed home, the compression of the rubber feeds the asbestos forward, so that a large proportion of the whole bulk can be actually worn away by the continual friction, before new packing is required.

It would carry this part of the subject to far too great a length, if even a summary account were given of the whole of the United Company's special machinery and manufactures; but it is evident that no one who has had an opportunity of considering the rapid advances made in the numerous and varied applications of this valuable material, will hesitate to admit that the persevering energy and practical skill exhibited by this Company have paved the way for other manufacturers, and that it can, consequently, claim to be the pioneer of most of the improvements which have been made in the machinery now in use for the manufacture of asbestos goods.

Before passing on to the consideration of Canadian asbestos possibly a few words may not be out of place here on the subject of the industry, as it is carried on in France, seeing that it is mostly Italian ore that is there used.

Attempts have more than once been made to establish the industry in France, at Mantes, Paris, and elsewhere, but, until recently, with no considerable amount of success. In the autumn of 1889, however, a more ambitious enterprise was set on foot by the establishment of the Société Française des Amiantes at Tarascon sur Rhone as a Société Anonyme. The business having been commenced on a scientific basis, was so far successful, that in order to obtain further capital, the undertaking was launched as an English Limited Liability Company in January, 1890, under the title of the "New Asbestos Company, Limited," capital £120,000. The asbestos deposits in the hands of this Company are 62 in Italy, covering an area of 700 acres, and 8 in France, extending over about eight acres. It has an establishment at Tarascon, for the manufacture of the

general run of asbestos goods, and another at Gadagne on the Saône for the making of millboard and paper.

The Italian mines are situate in the Valleys of the Saone and d'Aosta. The deposits in this district are essentially pockety, some of the pockets occurring on the level; most of the works, however, are on the slopes of the mountain, extending up to 700 or 800 feet of altitude. A rather primitive method of work is carried on here at present; this is a species of isolated task work, each workman, at the close of his day's work, conveying to the store the quantity of mineral he has himself extracted from the mine. When brought in by the men, it is bagged up, and at once transported to the works at Tarascon, where the bags are emptied and the ore dealt with in much the same fashion as that already described, with the object of loosening the fibres and separating them from the very large quantity of powdery admixture which is found in this Company's mines. After this initial process the crude asbestos is separated into three divisions, each destined for its special purpose :—

1. The long fibred quality is set aside for spinning and weaving.

2. The shorter fibred material is sent to Gadagne for millboard and paper.

3. The powdery material, part of which is converted into cement, paint, &c., and a considerable quantity sold to agriculturists for manure, and to viticulturists for use in the manner described in another chapter, as a protection against noxious insects infecting the vines. In regard to which M. Ville, a Parisian professor of chemistry, states that he has discovered a new chemical manure, intense and almost miraculous in its effects. This is a mixture of phosphate of lime, carbonate of potash, and sulphate of lime, which if placed round vine growths will enable them to defy the onslaughts of phylloxera.

CHAPTER IV.

CANADIAN ASBESTOS (*Chrysotile, Schillernder asbest*).

FIRST APPEARANCES UNPREPOSSESSING.—Hydrous Character—Colour—Description—Amianthus—Foliated and Fibrous Serpentines—Sources of Supply—Eastern Townships—Minerals found there—Position and Climate—Great Geological Fault—Serpentine Belt—Decomposed Serpentine—Dykes—Shickshock Mountains—Veins Irregular—Surface Influences—Trial Borings—Classes of Ore—Local Conditions—Prospecting—Chromic Iron—Impurities—Discolouration—Marketable value—Ornamental Serpentines.

DERIV.: χρυσος, gold, and τιλος, fine hair.

JUST about the time of the establishment of the London Company referred to in the preceding chapter, Canadian asbestos was beginning to attract attention, and it is not difficult to understand, how it came about that a Company which had not only practically originated the trade, but, by securing a large proportion of all the then known Italian mines, had, as they supposed, become possessed of a practical monopoly of the business, should, at the outset, have viewed the claims of a younger rival with jealousy, not unmingled with some degree of contempt. Nor was this last entirely unjustified, as first appearances were decidedly against the new comer. The Canadian ore was not only of an entirely different character from their own, and such as required altogether different treatment, but the staple was ludicrously short in comparison, much of it was coarse, and the rough and careless manner in which some of the crude ore was prepared for market, might

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CHRYSOTILE

readily induce anyone to believe it to be a decidedly inferior article. All that, however, is now matter of history, and Canadian asbestos, since then, has taken high rank among the economic minerals of the world; its most strenuous opponents have not only adopted its use, but urged by the necessities of their trade, have secured a mine in Canada, and have thus become producers as well as consumers of Canadian ore.

Chrysotile, to give the Canadian mineral its technical designation, is usually said to be a fibrous form of serpentine,* one of several minerals which, under certain conditions, have a tendency to assume that peculiar structural form.

According to local surroundings, chrysotile varies in colour from a greenish white or olive green to a yellow or brownish shade. For reasons already explained its analyses will not always agree, but the differences are not great, and for all practical purposes its composition may be taken to be :—

Silica	43·50
Magnesia. . . .	40·00
Oxide of Iron . . .	2·08
Alumina	·40
Water	13·80
	99·78

Sp. gr., 2·219. Optically it is bi-axial under polarized light.

Professor Dana says, it was first brought from Reichenstein, but, although it is found there, and in several other places, it is none the less the fact, that at the present time, it is not found of good quality, or in any considerable quantity, elsewhere than in Canada, and there only at present in one particular district.

A good popular description of the mineral was thus given in *Le Génie Civil* for September, 1883: "La chrysotile du Canada n'est pas comme l'amiante ordinaire formée d'un paquet de fils d'un blanc verdâtre et remplissant des

* "Fibrous serpentine with a silky lustre is called chrysotile."—Dana, "Min. et Lith.," 1878. "On appelle chrysotil une serpentine en fibres soyeuses, d'un vert tirant sur la jaune d'or, qui se distingue de l'asbeste par sa solubilité dans les acides et sa teneur en eau."—De Lapparent, 408.

cavités irrégulières: c'est une véritable pierre, d'une densité comprise entre 2 et 3, qui se trouve en couches de 3 à 10 centimètres d'épaisseur. Cette pierre possède la propriété de se reduire en fibres, perpendiculairement à sa longueur, sous un effort très faible. Ses fibres transversales sont plus résistantes et beaucoup plus facile à filer, à tisser, et à feutrer que l'amiante ordinaire." This is as good a description of chrysotile as can be found anywhere.

The finer and more silky varieties of asbestos are distinguished by the name of amianthus, which name is also frequently given to chrysotile, on account of the delicate appearance of its silky fibre.* When describing asbestos, Dana says amianthus includes the fine silky varieties. Much so called is serpentine, which is hydrous, and therefore easily distinguished.† Dr. Sterry Hunt says:— "Chrysotile constitutes the common amianthus, and has hitherto been regarded as a variety of serpentine, with which it agrees in centesimal composition. It is, however, distinguished from it by a lower specific gravity, and by its fibrous character, which, like that of amianthoide amphibole, indicates a prismatic crystallisation."‡ As a rule also, chrysotile contains a higher percentage of water. Professor Donald found the average quantity of water in five samples of Canadian serpentine, chosen at random from places in the asbestos district, to be 13·49 per cent, whilst in four samples of chrysotile, it was 14·25.

Fibrous and foliated varieties of serpentine are common in the ophiolites of the Silurian series, constituting the varieties described under the names of baltimorite, picrolite, marmolite, and chrysotile;§ true asbestos being a fibrous variety of tremolite ‖ or hornblende, both of which are essentially distinguished from chrysotile by their anhydrous character.

* "L'amiante, que l'on emploie dans l'industrie, provient généralement du Canada; il est fibreux, blanc et très refractaire."—Jagnaux, 1885, 551.

† J. S. Dana, 1878, 250, 308.

‡ "Mineral Physiology and Physiography," 1886.

§ Sir W. Logan, "Geol. of Canada."

‖ "La tremolite lorsqu'elle s'altère et devient hydratée, manifeste une

Baltimorite and picrolite are coarse, fibrous kinds of asbestos; the former ranking in the British Museum Catalogue as a variety of serpentine. It has all the exterior characteristics of asbestos, but in composition is somewhat analogous to antigorite. When free from admixture with iron its composition is—

Silica	42·97
Magnesia . . .	44·14
Water	12·89
	100·00

Another variety gives—

Silica	35·10
Magnesia . . .	42·20
Iron oxide . . .	10·50
Water	12·20
	100·00

Marmolite (from μαρμαιρω, to shine) is a foliated variety, usually occurring in thin, brittle folia. It is found at Hoboken, New Jersey, U.S.A., and was so called before it was known to be serpentine.

In a handbook, published in 1882 by the authority of the Dominion Parliament, it is remarked that what is commercially known as asbestos is really a term used "to denote a peculiar fibrous form assumed by several distinct minerals, rather than to designate any particular species. Tremolite, actinolite, and other forms of hornblende and serpentine, passing into fibrous varieties, assume the name of asbestos, and the 'Geology of Canada' does not give the mineral as a distinct one, but recognises it under these different headings. *As yet comparatively little asbestos has been found in Canada.*"

The stratified rocks with which serpentine is mostly asso-

tendence marquée à se deviser en fibres flexibles, à l'eclat soyeux, capables de former par leur enchevêtrement de veritables tissus mineraux."—De Lapparent, "Cours de Min.," 376.

ciated are black, green, grey, and purple slates, with, occasionally, conglomerates and sometimes beds of hard quartzose sandstone. The diorites, with which it is also associated, frequently form great mountain masses, as at Orford, Ham, Thetford, &c., and in texture are both massive and concretionary, while in colour they range from different shades of green to brown.*

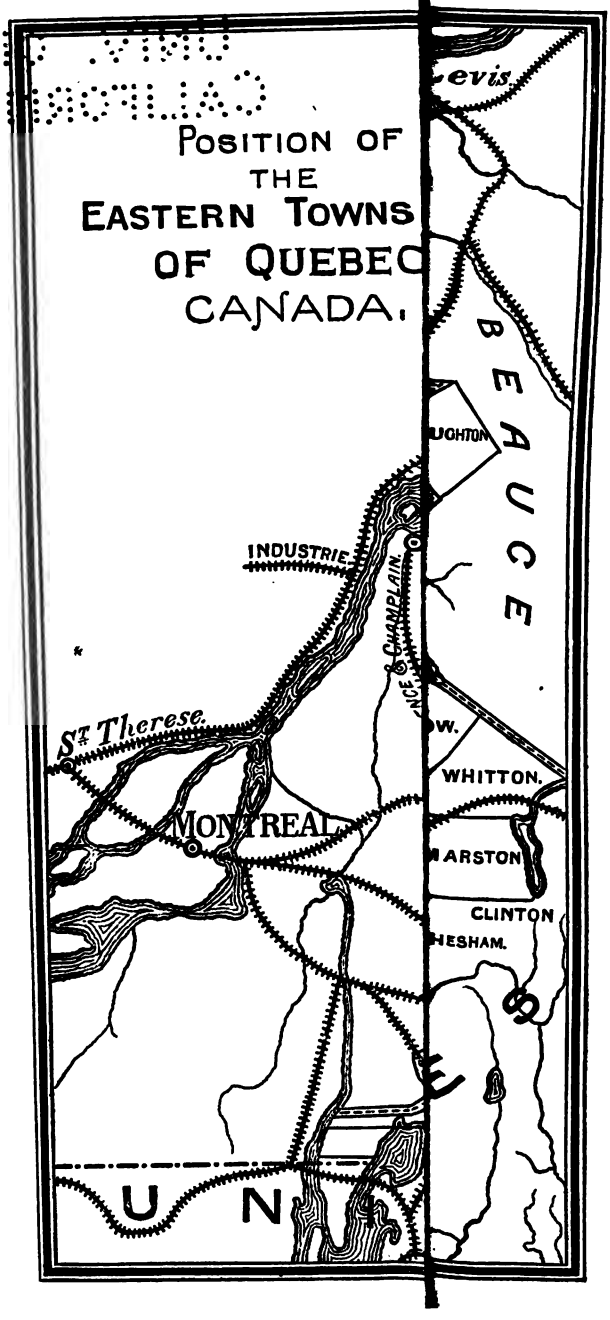
The main sources, from which the present supply of chrysotile is derived, lie within the province of Quebec, mainly within the counties of Wolfe, Megantic, and Beauce; the most productive of the mines, yet discovered, being situate in that part of the province which is known collectively as "The Eastern Townships of Quebec." Here the areas of serpentine are very extensive and prominent, but those portions on which the mineral abounds are comparatively rare, and are practically limited to two small sections lying about four miles apart. Other promising sections are being carefully explored, but these are as yet mostly covered with soil and forest, which obstruct investigation.

The district comprising the Eastern Townships, like the more southern part of the province of Ontario, which lies on the opposite side of the river, (notwithstanding that the rock formations of the two districts differ materially), is singularly rich in deposits of minerals, not only of vast extent, but of a very diversified character. In the Laurentian Strata of Ontario, as well as in the Ottawa district of the Quebec province, the rocks are mostly pyroxenic, and abound, the latter especially, in apatite,† whilst those of the crystalline and subcrystalline formations which traverse the Eastern Townships and run through the Gaspé peninsula, are mostly of a hydrous character, magnesian and chromiferous; and it is chiefly among these last that the serpentine, which forms the asbestos matrix, occurs. Asbestos is found in the serpentine limestones of the Laurentian series also, but little has yet been done there in

* Dr. Ells, "The Ottawa Naturalist," vol. iii., no. 2.

† "Apatite occurs, without exception, in association with pyroxenic or hornblendic rocks."—Penrose on "Apatites," 25.

CALIFORNIA


POSITION OF
THE
EASTERN TOWNS
OF QUEBEC
CANADA.
Levis.
BEAUCE
UGHTON
INDUSTRIE.
CHAMPLAIN.
St Therese.
W.
WHITTON.
MONTREAL
ARSTON
CLINTON
HESHAM.
U N

the way of productive mining, although discoveries are likely to follow scientific prospecting.

Dr. Ells remarks that the areas of serpentine are very extensive in the two great geological formations of Canada; in the Laurentian, which stretches from the coast of Labrador to westward of the Great Lakes, covering an area of about 200,000 square miles, and the Quebec Group, which occupies a large portion of that province lying southward of the St. Lawrence, and between that river and the United States boundary. What may be termed the asbestos district in the Eastern Townships is a vast area of about 200 miles in length, by 6 or 8 miles wide,* the asbestos found here differing in many respects from that found in the Laurentian district.

That part of the country, which goes by the name of the Eastern Townships, includes the greater part of the province of Quebec, which lies on the southern side of the St. Lawrence. Its relative position as regards the cities of Montreal and Quebec and the river, will be seen from the sketch-map of part of the province annexed. It forms a narrow zone of metalliferous rocks, within which is comprised the greater part of the mineral wealth of the province. The deposits which occur in this part of the continuation of the Appalachian region, some of which are of great extent, comprise gold, silver, copper, galena, asbestos, antimony, nickel sulphide, pyrites, magnetic, chromic, and titanic iron ores, bog ore, steatite, and roofing slate; whilst many of the crystalline dolomites are intermixed with serpentine in such a way as to form black and gold, green and chocolate-coloured serpentine marbles, some of them of great beauty.

A general view of the mineral industry of the province is shown by the following table, which gives the production and value of the minerals for the year ending 30th June, 1889.†

* Dr. Selwyn, *Canadian Mining Review*, no. 6.

† "Rapport du Commissaire des Terres de la Couronne de la Province de Quebec pour les douze mois expirés le 30 Juin 1889."

	Tonnes.	Value.
Phosphate	28,350	$460,950
Amiante (asbestos)	5,919	352,260
Cuivre	70,955	720,000
Fonte manufacturé avec bog-ore	4,000	120,000
Fer (minéral exporté)	3,000	15,000
Or	,,	,,
Graphite	450	23,500
Mica	,,	,,
Feldspath	250	1,750
Soapstone	150	1,200
Ardoises	20,300 square	90,000
Granit	30,000 pds. cub.	12,000
Calcaire à bâtir	200,000 vrg. cub.	200,000
Chaux	400,000 minots	70,000
Briques	30,000 milles	200,000
		$2,266,660

M. Mercier sums up the matter by stating that this mineral region contains about 1,000,000 acres of iron-bearing lands, 500,000 of apatite ground, 100,000 asbestos, 50,000 copper, 100,000 auriferous, and 10,000 oil bearing; forming a total of mineral wealth covering 2,000,000 acres of land, mostly in workable deposits.* The metalliferous zone covers the whole district, extending thence to the extreme east of the Gaspé peninsula. This latter region, on account of the dense forests which cover the greater part of it, the want of roads and other obstacles, has not yet been sufficiently explored to bring its mineral treasures to light. The Minister of the Interior, in 1882, reported to the Dominion Parliament, "We can affirm that this vast country constitutes the principal zone *minière* of the Eastern Townships. The zone extends from the frontier of the United States to the north-east of Quebec. Until now (owing to the difficulty of exploration) we have not found anything more than serpentine rocks and chromic iron in the region of Shickshock; but as these minerals are generally found with cotton-stone, brass, lead, antimony, and iron, also

* "General Sketch of the Province of Quebec," by the Hon. W. Mercier, Premier of the Province.

with gold and silver, it is not unlikely that we may find those minerals in the unexplored region of Gaspé."

The foregoing statement is corroborated by Professor Hunt, who, in 1865, wrote :—"The Eastern Townships are included in the rising zone, situated to the south of the St. Lawrence, as well as the more south-eastern region extending along the frontier, and forming a succession of valleys, which continues from the sources of the river Connecticut to the north-east of the Baie des Chaleurs. The Eastern Townships do not include this prolongation towards the north-east, but, as it geologically and geographically belongs to them, we may include it under the same name."

Since the above was written further progress has been made in the exploration of Gaspé, and it may be said that all the minerals found in the Eastern Townships abound there also, with rock oil in addition.

The volcanic range, which at the extremity of Gaspé is lost in the sea, practically passes under it, and rises again on the shores of Newfoundland, where the formation is the same, and where asbestos, gold, and many of the other minerals named, are also found.

Until the comparatively recent discovery of the chrysotile mines at Thetford, the district comprised within the Eastern Townships was but sparsely occupied, being, in fact, in much the same condition as Gaspé is to-day; but the discovery of asbestos, with the pecuniary success resulting from the working of the mines, has had the natural effect of attracting thither large numbers of the mining and trading classes, and continued success has so rapidly increased the population, during the last few years, that this district now promises to speedily become a populous, thriving, and most important part of the Dominion. And this result is likely to be a good deal facilitated, as well by the comparative mildness of the climate, as by the fertility of the soil, in this part of the province. It is unquestionably true, that the cold here is more rigorous than any experienced in England, the snow is deep and lasting, and the broad St. Lawrence is regularly frozen over. It is true, also, that no

climate in the world can exceed that of England, in its pure balmy, delicious atmosphere during, perhaps, a few days in early summer and autumn; but when it is considered how lamentably few those days are, it may be that the balance of enjoyment might be awarded to this part of Canada; for, notwithstanding the rigour of winter, the air there is so dry and exhilarating, as to render the cold far less disagreeable and hard to bear than what we have to endure in England, where a warmer temperature prevails, accompanied by humid and foggy atmospheric conditions. As a rule, people suffer much less from cold in Canada, than they do in England,* and pulmonary and bronchial affections are not so prevalent. An unfortunate association of ideas, rather than actual fact, by which Canada is not the only sufferer, has caused the words Canadian, Siberian, and hyperborean to be deemed interchangeable terms in popular estimation denoting the utmost severity of cold. †

In regard to fertility, we have the authority of Dr. Ells for stating, that much of the Eastern Townships district is underlaid by a broad band of slaty rock, with which a considerable development of limestone is associated, the decay of which produces a soil of great value to the husbandman.‡ The hard rocks of the Laurentides also are intersected in all directions by bands of crystalline limestone, of a soft and decomposing nature, which render the ground, especially in the valleys, very fertile.

Considered in relation to the mineralogy of this district, a matter of great importance is that nearly the whole of it is crossed, near the central line, by the great mountain range which forms, on the south of the St. Lawrence, a continuation of the Appalachian chain of the United States (of which the Alleghanies are an offshoot), and which, where it traverses

* Much the same may be said of the cold in Russia. Barry remarks: "I never suffered from the climate in Russia, even in the severest weather, so much as I do in England."—"Ivan at Home," p. 119.

† "Canada," 1886, p. 1.

‡ "Notes on the Economic Minerals of Eastern Quebec."

Canada, is locally known as the Notre Dame and Shickshock Mountain range. From Gaspé to Quebec this chain forms the watershed between the basin of the St. Lawrence and the Bay des Chaleurs and Bay of Fundy to the south; and throughout the whole of this region serpentines abound.

The range, as it passes through the Townships, gradually approaches the river, running along its southern shore, at a distance varying from 10 to 30 miles inland, and terminating in the high tableland of Gaspé, at the eastern extremity of the province. It consists of several roughly parallel lines of mountainous country, showing one or two points of nearly 4,000 feet of altitude (the elevation in the Gaspé peninsula averaging 1,500 feet), which is cut by deep gorges through which the rivers flow; it is largely made up of crystalline magnesian rocks, including talcose and chloritic schists and beds of serpentine, in places associated with micaceous and gneissoid rocks and other crystalline deposits. Cambrian slates and other strata have here been thrown up by a great fault, into a position apparently higher than the Hudson River beds. This fault touches the boundary of the province, not over a couple of miles from Lake Champlain. From this it proceeds in a gently curving line to Quebec, keeping just north of the Fortress. Thence it coasts the north side of the Island of Orleans, leaving a narrow margin, on the island, of the Hudson River and Utica formations. From near the east end of the island it keeps under the waters of the St. Lawrence to within 80 miles of the extremity of Gaspé. Here it again leaves a strip of the Hudson River or Utica formation on the coast.*

Resulting from some mighty convulsion, which has left indelible traces behind it, the country, near the great fault, traversed by the mountain range, has evidently been subjected to enormous pressure, either arising from a shrinkage of the earth's crust, or by a forcing upward of the lower strata; the whole of which, or that part of it which lies south and east of

* Second Report on the Geology of a Portion of the Province of Quebec, 1888.

the fault, has been greatly disturbed and broken up, and more or less altered by metamorphic agencies. Crystalline, gneissoid and magnesian rocks appear in part to underlie them and partly to be mixed up with them in intricate foldings, by which their stratigraphic relations become greatly obscured. In many places, also, they are broken through by trachytic and granitic masses. Whilst to the west and north of the great fault the strata are particularly undisturbed, those which lie directly east and south of it have been greatly tilted and uplifted, and generally reversed in dip. Towards the more central parts of the district, many of the beds have been altered and rendered crystalline by metamorphic agencies, and these have been folded up with one another and with an older system of crystalline rocks, forming the axes of the higher elevations in such a way as to produce great complications of structure. In its physical features the district is more or less of a mountainous character throughout, and in parts, as already stated, of considerable fertility. In this latter respect it differs remarkably from the mountainous Laurentian region of the northern part of the province. * The general features of the country, therefore, are very singular, having a rolling appearance, and, when viewed from any altitude, looking like an upheaval of mighty waves suddenly stilled and changed into stone. In his description of the mineral region east of the Rockies, Professor Geikie describes its peculiar uplifted formation, which is much similar to the region described above; there the ancient granitic and crystalline rocks † have been driven up like a huge wedge through the younger strata of the prairies, and now form the axis of the Colorado Mountains, respecting which the Professor remarks that, had it not been for this wedge, the "Centennial State" would have been

* Chapman on the "Geology of Ontario and Quebec," part 5.

† The author of "Les Schistes Crystallines" maintains that the designation of "crystalline rocks" is defective, inasmuch as we find associated with masses having a right to this title, and geologically confounded with them, other rocks, such as serpentine, obsidian, perlite, &c., which are not crystalline in character, but colloidal or porodic.

a quiet pastoral or agricultural territory, like the region to the eastward. The rise of the granite axis, however, has brought up with it that incredible mineral wealth which, in a few years, has converted the loneliest mountain solitudes into busy hives of industry. *

It is through the crystalline formations of the district bounded by the great fault that the belt of serpentine runs, in which the chrysotile is found. The serpentine itself is one of the altered igneous rocks of metamorphic origin, arising from the transmutation of magnesian limestone or some closely related strata. By the earlier geologists serpentine was called "a mysterious rock." In alluding to pikrite,† a bitter fibrous variety of serpentine, Cole says that perhaps among all the rocks of igneous origin, there are none which so much puzzle the petrologist in his attempts at a rational classification as the small group which seem to pass into serpentine. Comparatively few such rocks have yet been discovered, but whenever the stratigraphical details have been worked out, in conjunction with their mineralogical characters, they seem to establish the igneous origin of serpentine.‡ De Lapparent calls it a colloid mineral, which, he says, holds in suspension the fine fibres of the minerals at the expense of which it has been formed,§ these fibres being distinctly seen in the compact rock under polarized light.‖ Gages formed it artificially in a transparent amorphous mass by placing a solution of gelatinous silicate of magnesia in a dilute solution of potash, the serpentine being deposited after some months' standing.¶

The rocks from which serpentine is mainly derived by an aqueous process are called peridotites, though there are several varieties which receive distinctive names. They are all

* Geikie's "Geological Sketches," 216.

† Or pĭcrīte, from πικρος, bitter, from the quantity of magnesia or bittererde present.

‡ "Studies in Micro. Science," art. "Pikrite."

§ "Cours de Min.," 408.

‖ "Im polarizirten Licht bemerkt man aber, dass auch das dichte Mineral aus höchst fein faserigen Theilchen besteht."—Tschermak., 494.

¶ "Report British Assoc., 1863," 203.

characterised by the predominance of the mineral peridote or olivine. Peridotites are not commonly found on the earth's surface, one reason being that olivine is an unstable mineral which readily absorbs water and passes into serpentine.*

As implied by its name, serpentine† (lapis colubrinus) is so tinted by association with other minerals, with chrome iron especially, as to exhibit a diversity of shades and colours which give it a mottled or spotted appearance, bearing a somewhat fanciful resemblance to the markings on a serpent's skin. For this reason Agricola named it serpentaria. It is also sometimes called ophiolite, and the commoner sorts ophite, both names being derived from ὄφις, a snake. The Italians look upon it as more froglike, and therefore call it rannócchia. Mineralogically it is a hydrated silicate of magnesia, something like talc, but with more water and less silica; it is somewhat soft and sectile, has a dull, splintery fracture, and a soapy unctuous feel. It occurs generally in compact granular, slaty masses, and when found disseminated through granular limestone it imparts to the latter a clouded green colour, forming what is called verd antique.

It is sometimes found, especially in Northern Italy, to be decomposed to a considerable depth, and frequently parts, in decomposing, with a large proportion of its magnesia and most of its alkalies. In addition to the formation of unctuous clays, this change sets free carbonate of magnesia and silica, which are deposited in veins traversing the altered rock. Bischoff proved experimentally that carbonated water is capable of decomposing the silicate of magnesia, and of carrying some of it off in the form of carbonate; and Rogers has shown that digestion in simple water for three days is sufficient to remove an appreciable amount of magnesia from even such minerals as hornblende.

The rocks in which the asbestos-bearing serpentine is found

* Major-General McMahon, "Discourse before the Western Micro. Club, 1890."

† Etym.: Lat., Serpentinus; Fr., Serpentine; Sp., Serpentin; It., Serpentino; resembling a serpent.

are closely associated with masses of diorite or doleritic rocks, of certain varieties of which, rich in olivine or some allied mineral, the serpentine is in many cases an altered product;* and the asbestos, which is found in this serpentine, a still later product of alteration. These rocks are frequently associated with masses and dykes of whitish-looking rocks, composed of quartz and feldspar, with which there is occasionally a mixture of black mica, forming a granitoid rock, and almost always with magnetic and chromic iron ores. In St. Francis, Beauce County, the serpentine occurs in connection with magnetic and titaniferous iron; in Roxton, Brompton, and some other places it carries copper pyrites and other copper ores.

The serpentine rock forms part of the great volcanic belt traversing the Eastern Townships, which can be traced with tolerable clearness, though with frequent and considerable interruptions, throughout a course of over 120 miles in length, in which it sometimes attains a width of more than 2,500 feet, bearing mostly from north-west to south-east, following in this respect the general trend of all fissures charged with metallic ores, which usually have an east and west direction, varying about 45° on either side.

That portion of the belt which more immediately concerns our subject, runs from the boundary of Vermont, ~~in the State of Maine~~, to some distance beyond the Chaudière river, a little past the latitude of Quebec, traversing in its course the Townships of Potton, Bolton, Orford, Brompton, Melbourne, Cleveland, Shipton, Ham, Garthby, Coleraine, Thetford, and Broughton. The course of the belt, in its entire length, will be found elaborately traced out and described, in a very interesting report, by Dr. Ells on "The Geology of a Portion of the Eastern Townships," published by Dawson Brothers, Montreal, in 1887, by authority of the Dominion Parliament. Here it will be seen that in Cleveland and Shipton the belt assumes a transverse twist, which also affects the Cambrian and other formations in the vicinity, and changes the strike for some miles, in the townships of Wootton and Ham to an almost

* Dr. Ells' Report, 1886, Part III., p. 23.

easterly course. The prolongation of the Melbourne and Shipton ridge, which terminates in the Little Ham Mountain, after an interval of about five miles, occupied by slates and sandstones, reappears in the Big Ham Mountain, which rises boldly from the somewhat flat country at its base, to a height of 1,150 feet, forming a magnificent hill feature of the landscape.

The most important area is that which, terminating southward in Big Ham Mountain, extends north-easterly to and beyond the Chaudière. In this area serpentines are first seen in several hills, on the south side of the outlet of East Nicolet Lake, and both here and on the west shore (where a vein of magnetic iron occurs, having a thickness of 6 feet at the surface, increasing to 11 feet in the shaft at a depth of 12 feet), the serpentine is dark green, and contains a small quantity of grey copper ore. According to Mr. Coulombe, who first opened this mine in 1881, the serpentine extends south-east from this point to near the foot of the Ham Mountain. It occupies also all the islands in the lake, and the south and east shores, extending in a ridge to the road leading to Garthby village. On the south end of the lake there is a considerable area of soapstone. The principal mass of serpentine stops at Lot 55, but is found associated with diorites on the Garthby road. It again prominently appears on a ridge near the road leading from Wolfestown to Coleraine Station; on the north-east flank of which ridge the Belmina mine is situated. Here the serpentine is associated with considerable masses of the whitish granulite already mentioned. These appear occasionally to cut the serpentine after the manner of dykes, and to its presence may possibly be ascribed some of the frequent faults which affect these rocks, and which are disclosed in the asbestos workings. There can be no doubt that the presence of these dykes favourably affects the quality, as well as the quantity, of asbestos; in corroboration of which opinion may be alleged the well-known fact that the nearness of a fault may be often predicated by some sudden change in quality, whether for better or worse, in respect to the veins

of many other minerals besides asbestos. This granulite, interstratified in a peculiar manner, is to be distinctly seen in some of the mines at Thetford as well as at Coleraine. In the latter place, it is found in all the mines on the western side of the serpentine ridge, and there the asbestos is abundant and good; but, directly the ridge is crossed, the granulite disappears, and the serpentine is found to be barren of fibre. This remarkable fact cannot at present be accounted for, nor is it known why the granulite exercises this influence over the serpentine. It is clear, however, that these intrusive rocks are newer than the serpentine which they traverse, as their intrusion is marked by the alteration and shattering of the mass traversed along the contact with these dykes. The white masses of these granulitic rocks, which are such an important feature in the serpentine areas of Coleraine and Thetford, form hills between Black Lake and Thetford, and are very conspicuous as seen from the railway.*

Crossing into the adjoining townships of Ireland and Coleraine, the serpentine forms part of a harsh, rugged-looking country to the west of the Quebec Central Railway, the boldly outlined peaks and ridges to the south-west of Black Lake forming also very prominent features in the landscape. These

* This semi-granite is the name of an elvanic or fine-grained rock containing in itself alkali, in the form of potash and soda, sufficient to melt the silica of which it is principally composed. It has been used for some time in the manufacture of glass, which, being the product of silica, a most refractory mineral, requires alkali and other fluxes to secure its fusion, whereas granulite requires no such flux to melt it beyond lime. The fine feldspathic granulite at Meldon, Dartmoor, is even finer than that found in Saxony; assays of this show—

Silica	69·34
Mixed oxide of iron and aluminium	3·56
Lime	1·34
Magnesia	1·00
Alkalies	23·36
Calcination loss	1·40
	100·00

ridges take their rise a short distance north of the boundary between Ireland and Wolfestown, extending thence into the Township of Thetford. In the vicinity of Black Lake Station, and between this point and Thetford, the serpentine is largely intermixed with granulite, and in so far as is yet known this area constitutes the richest asbestos ground in the province. The country rock in the great serpentine areas of Thetford and Coleraine is a black, greenish slate, with hard schistose quartzite; but at Coleraine Station beds of dark red slates, mixed with conglomerates, occur.

Large areas of the volcanic rocks also occur in the Shickshock mountain range, in the northern part of Gaspé, in rear of St. Anne des Monts, the most easterly point being Mount Serpentine, about ten miles up the Dartmouth river from its outlet in the Gaspé basin. This district was partially explored by Mr. Obalski in the summer of 1889, and he states that Mount Serpentine, which rises 1,600 feet above the sea level, is not, as its name would lead one to suppose, composed of serpentine, but of hornblende. He, however, established the existence of a band of serpentine on Block 19 there, in which he saw numerous small veins of chrysotile. A specimen from this district in my possession cannot be distinguished from the usual run of Thetford ore, which proves the desirability of a thorough investigation of this as yet unknown region. The serpentine here is associated with limestone, and is surrounded by strata of Devonian age; to the west lies the great mass of Mount Albert, whence the ridge extends westwards for some miles. Indications of asbestos are found at most points throughout the whole formation; but, so far as is at present discovered, the mineral is most abundant in the localities named above, although there is certainly no reason why it should not be found in paying quantity at other points, especially as it is now well established that the masses and dykes of granulite already referred to favourably affect the presence of asbestos.

Traversing the serpentine in irregular veins, the fibre, unless affected by the dislocations of the containing rock, or

distorted by pressure, always lies in parallel lines at right angles to the sides of the fissure. In many cases, the veins are rendered impure by the admixture of grains, or small, irregular threads, of chromic iron or of magnetite, which break the continuity of the fibre, and then the mineral has to be carefully cobbed in order to get rid of these impurities. Near the surface, also, the veins are occasionally affected, to some extent, by the infiltration of water, often impregnated with metallic oxides, the asbestos being thereby discoloured and its value diminished. This is especially noticeable where the serpentine is disintegrated or shattered at the surface, by the action of the weather, or other causes; but the discolouration ceases as soon as the rock becomes solid. The size of the veins varies greatly, and, like other mineral veins, as already mentioned, they are affected by faults or slides, which occasionally cut off completely a valuable working face. In these cases, the slickensided character of the faces of the fault is very marked, and sheets of impure or imperfectly formed asbestos (picrolite) are found lying among them along the planes of fracture. The veins have frequently the aspect of true segregation veins, and the containing walls have, in many places, a different aspect for a distance of half an inch to three inches on either side.

Mr. Obalski, Government Mining Engineer of Montreal, states that, when tracing out the bands of serpentine, he established the existence, north of Little Lake St. Francis, of a wide band of the dark-green rock containing asbestos not yet worked, or even explored. This crosses the Indian reserve, and a block not named in the map, which he calls Block K. It then enters Ranges B and A of Coleraine, and probably Range A of Thetford. Dark serpentine then ceases to be found, and a light-coloured variety appears in the neighbourhood of Lake Bécancourt, and in Ranges 8 and 10, where a little asbestos is found, but of inferior quality.

Asbestos of good quality has also been found at Shefford, on the line of the Quebec Central Railway, the deposits being pronounced by Professor Selwyn as very promising.

Good specimens have likewise been obtained at the Chaudière River, and a small quantity from the river Desplantes, one of its tributaries.

Some years ago a few tons were taken out of the Laurentian rocks in the Papineau Seignory; but, for some reason or other, the discoveries there made were not followed up.

On Lots 10 and 11, Range 8 of Templeton, there are two contiguous workings, from which a sample ton was sent to Ottawa in 1879, realizing 100 dols., a good price at that time.

A sample sent me from Lot 8, Range 10 of Templeton, is of a striking character. Like all that found in the Laurentian strata, it is essentially different from the Thetford or Black Lake ores, being of a singularly light colour and of such special brilliancy as almost to appear semi-transparent.

The company formed to work the deposits at Brompton Lake are now turning out some good material. The fibre, though comparatively short, is of good quality, and remarkably free from iron.

Traces, also, are to be met with at Chelsea, and on Meech's Lake, as well as in the hills running northward of Ottawa city. The indications thereabouts are so good that geologists are disposed to think that mining for asbestos in the Ottawa Valley will presently assume some importance.

Fibrous hornblende is plentiful at Cape Breton; but no true asbestos has yet been found there. Gesner* states that samples of asbestos were found in Clare Township, N.S., with fibres radiating from a common centre. These were found in veins penetrating a rock compounded of slate, quartz, and feldspar, and were probably radiated actinolite.

In its pure state, chrysotile is as heavy as the rock in which it is enclosed, so compactly are its fine crystalline fibres compressed together; but when once it has been disintegrated, it is quite impossible to pack or knit the fibres together again, in such a way that they cannot be easily separated by the fingers.

The veins nowhere present themselves in uniform abundance, although rich veins are sometimes opened up which have a

* Gesner's "Geology and Mineralogy of Nova Scotia," 1836.

certain continuity. As a general rule the quality of the ore improves, and the quantity increases, as the workings are prosecuted to greater depth; nor is it difficult to comprehend why this should be so. Moreover, as has been before remarked with reference to Italian asbestos, the better qualities are usually procured from deposits at considerable altitudes; these, however, are not so great in Canada as in the Italian Alps, the altitudes in Coleraine and Thetford ranging from 700 to 800 feet, although some of the unworked parts of Coleraine are higher even than this.

The probabilities also point to a continuation of the deposits to some considerable depth, though that important matter cannot at present be proved in the absence of deep workings. No trial borings have as yet been made anywhere, except on a limited scale, by Mr. Sheridan, at Thetford; but in one mine there a depth of about 200 feet has been reached without any indication of a cessation, or any diminution of the quality of the ore. The desirability of testing the lower portions of the serpentine have often been advocated in the Reports of the Geological Survey, but, as has been already observed, up to the present very little in this way has been attempted.

As a general rule the harder and darker-coloured serpentines are the most productive, the light-green rock being usually either sterile, or yielding only a brittle quality of ore, to which but little value is attached. An exception to this rule occurs at Broughton, where a pale rock is found accompanied by splendid fibre. Admixtures of hard and soft serpentine occasionally occur; but when this happens successful mining is always doubtful, whatever may be the nature of the surface indications. Should the serpentine be crossed by quartzose gneiss or transverse dykes of granulite, the prospects are much better, especially at the junction with diorite, the contact with granite being by no means so favourable.

The chrysotile found in the Eastern Townships may be roughly divided into three classes :—

a. A coarse, brittle, compact variety, plentiful, but of comparatively little value.

b. Ore possessing well-defined fibres, of a yellowish-brown colour, fragile, and containing much foreign body; and

c. A pure, white, silky, fibrous quality, easily separable by the fingers, and much of it adapted to the manufacture of textile goods.

The last-named variety is that chiefly sought after, and this is graded at the mines into three classes, known commercially as Nos. 1, 2, and 3, according to quality of fibre; No. 1 commanding the highest price, as being considerably superior to the other two. This, when of a pure white colour, and free from silicic acid or metallic oxide, is rendered specially valuable by its native lubricating qualities, which last property is also possessed by one, at least, of the Italian varieties, and is owing to the presence of the large amount of magnesia in its composition. It is also said to constitute the chief value of a particular kind which occurs in parts of the United States.

Veins of six inches or more in width are often spoken of; but samples of such a width as that, when found, are usually preserved as specimens, being by no means of frequent occurrence, even at Thetford, where, as a rule, a narrower fibre prevails. A width of one and a half or two inches is as good as any that can be had. Some specimens of Thetford ore now before me are by no means wide, but are of singular beauty, and are certainly both broad enough and good enough for any purpose to which the fibre could possibly be put. On this point extraordinary ideas occasionally prevail among persons whose knowledge of the subject is limited, probably engendered by confounding Italian asbestos with Canadian chrysotile. An instance of this came to my knowledge quite recently. A gentleman who was commissioned to inquire for a good Canadian mine, for some parties in London, called upon me for my assistance in procuring one likely to suit the proposed buyer. Upon talking the matter over, he told me that unless the average of the fibre was about 12 or 14 inches it would not suit, and then passed on to the question of price. To his great surprise, I stopped him, by saying that it was useless to go into the question of price because, as a matter of

fact, such a mine as he was desirous of purchasing had no existence in Canada, or, as far as I knew, anywhere else.

It must, however, be borne in mind, when discussing the width of veins, that the same rule holds good with many other things which is observed in the vegetable world, namely, that the largest specimens are not necessarily the best. Large crystals, for instance, seldom have the perfection and transparency of those of smaller size; the finest qualities of wool are comparatively short in staple; * the largest varieties of fruit are seldom the most succulent; † and so it is with asbestos. The broadest veins do not, as a rule, yield fibre of so fine a quality as those of a medium, or even of a comparatively small size. Moreover, the length of fibre cannot be determined with any certainty from the thickness of the vein. On the contrary, the broader veins are not seldom found to be separated at right angles to the length of fibre by minute bands of serpentine, chrome, or magnetite, sometimes even by a separation, without any perceptible layer of rock, the only indication of this being an irregular, scarcely visible line, readily detected by the expert. In many places the serpentine contains magnetic iron, disseminated in fine particles, the associated asbestos showing the same iron, not disseminated, but usually concentrated towards the middle of the vein. It seems evident, Mr. Donald remarks, that both the serpentine and iron oxide have been dissolved by percolating water, and redeposited in the crevices of the rock; the less soluble silicate first, and lastly, in the middle of the vein, the more soluble iron. ‡

Under the hammer the big veins, in which the separation exists, are at once divided into two, or it may be into three, lengths of fibre; but if the cotton be pure and clear, this is no

* "Wool is divided into two classes, known as short or carding wool, which seldom exceeds 3 or 4 inches in length, and long or combing wool, varying in length from 4 to 8 inches."—Dr. Bowman on "Wool Fibres."

† "The Russians are probably the possessors of the largest grown peach in the world; it is called the 'Venus,' and is of a magnificent colour. I have picked three peaches weighing 2¼lbs. They are better, however, to look at than to eat."—Barry's "Ivan at Home."

‡ "*Canadian Record of Science*," April, 1890.

very great detriment. Veins of an inch, or an inch and a half, extracted from compact rock, seldom have these intersections. The veins, moreover, are extremely irregular in character, a small vein at the surface frequently developing into one of considerable size lower down, or breaking off altogether. This is the special characteristic of the veins in the Coleraine district—notably at Black Lake—at the mines of the Anglo-Canadian Company, and at Danville. At Thetford, on the other hand, where the ground is of a more uniform character, fine veins are frequently met with just below the surface, which continue with very little change (unless crossed by bands of granulite, when the course is interrupted), for a considerable distance.

Another special point to be noted is that the probabilities of successful mining are much increased if the indications are found on the hill side, among the rugged rocks, where the surface is but sparsely clothed with soil. The serpentine, it is true, frequently underlies cultivated ground, but in such cases the rock, when reached, is generally found to be comparatively sterile. The harsh and rugged-looking Coleraine mountains, which the forest fires have denuded of trees, and on which little or no good land is found, offer every induce ment to the explorer; while, on the other hand, a district like Danville, where good land abounds, cannot be nearly so profitably worked. In Thetford, again, where the land about the mines is somewhat flat, the best workings have been found on the hill or knoll where there was but little superincumbent soil, the colouring matter from which could, by capillary flow, or through the planes of cleavage, penetrate the loose or shattered and decomposing rock, and deteriorate the value of the fibre by discolouring it. One of the mines there could of course be cited to show that this rule is not of universal application; three out of the four were opened on the knoll, but in the case of the fourth, about 30 feet of overlying clay and gravel had to be removed before the rock was reached. When this was opened, however, veins of fine quality were disclosed which have since been successfully worked,

although the lower level at which they occur causes difficulty with water.

Certain peculiar conditions, as already mentioned, possibly connected with the intrusive bands of granulite, appear to have prevailed in Thetford and the more northern part of Coleraine, which have led to the formation of asbestos in special abundance, the veins being found interlacing the rock in all directions.

This rock, except at Thetford, is usually so split up and seamed, in every direction, by the veins and stringers of asbestos that, excepting at Broughton, where the formation is peculiar, tunnelling, as carried on in Italy, cannot be adopted. Possibly when greater depth is reached, and the rock becomes more solid, means may be found to advance the work in this way; but at present open quarry working is the rule, the main disadvantage of which is that the work necessarily suffers in bad weather, and is of course considerably interrupted by heavy falls of snow in winter.

Chrome iron and magnetite, always found in association with the asbestos-bearing rocks, are frequently found, as at Thetford and Lake Nicolet, in large deposits close by the mines, and it has already been explained how the fine, thread-like veins of these metallic ores cut and destroy the continuity of the fibre. It is a curious thing that the asbestos seems to deal with these ores, in precisely the same way, for on examining the specimens of iron ores, brought by me from the neighbourhood of the asbestos mines, the stringers of asbestos, although very minute, are found intersecting them in a precisely similar manner.

The various distinguishing characteristics of the ore of the different mines are of so marked a nature that an expert can often determine the locality of the mine from which a sample has been taken, and occasionally name the mine itself from an inspection of the ore. This fact is worth noting, as it should effectually prevent the fraudulent substitution of one ore for another, which has been sometimes successfully practised.

The rock also varies considerably, and requires careful ex-

amination. In some places it is apparently still in the transition stage between the original rock, from which it is derived, and a true serpentine having almost the hardness of feldspar, while it yet retains the general aspect and colour of the serpentine in which it is found.

At nearly all the mines large quantities of so-called bastard asbestos (picrolite) are found. This is a woody, brittle variety of, apparently, as yet unformed mineral, for which at present no use seems to have been found; but, judging from its composition and the new applications of the mineral now being introduced, there can be little doubt that this inferior article will presently command its price in the market, a use being found for it in some of the many purposes for which coarse pulverised asbestos is applicable.

Occasionally very singular types of ore are also to be seen. Some of the pieces, of the nature of mountain wood, as they lie on the ground, after blasting, have so much the appearance of a wood-cutter's choppings (being in the coarse and peculiar grain of the fibre so like chips of wood) that, if placed side by side with actual chippings from rough timber exposed to the weather in the woods, the one could not be distinguished from the other, except by handling, when the weight and stony feeling of the asbestos would make the difference at once perceptible.

The characteristic colour of the ore largely depends upon the locality of the mine, and the nature of the rocky gangue. At Thetford it is of a greenish hue, being there found in the darker coloured serpentine; whilst at Broughton the ore is of a pearly yellowish green, the surrounding rock being mostly of a grey or pale green colour. This difference of colour in the ore, however, in no way affects the value of the mineral, as, when crushed out, the fibre is mostly of a uniform whiteness.

When treating of asbestos, serpentine must necessarily always be present in the mind, and whatever relates to that rock must consequently be interesting and worthy of note. It may, therefore, not be altogether out of place here to mention that serpentines of an ornamental character are abundant

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PICROLITE, "BASTARD ASBESTOS."

in Canada. Some very beautiful specimens were shown in London, at the late Colonial and Indian Exhibition at South Kensington. Many of these contain small quantities of chromium and nickel, and are associated with soapstone, potstone dolomite, and magnesite. A band of limestone also occurs at Templeton containing masses of a light-coloured translucent serpentine. These ornamental serpentines are exploited with some success by the Canadian Granite Company of Ottawa, and are used by them for monuments, mantelpieces, vases, and such like. One would certainly think that their importation into England would meet with success, seeing that there is always a demand here for fine marbles and stones for architectural and other purposes. Variegated serpentine marbles of great beauty are found at Gaspé also, especially about Mount Albert, where the mass of serpentine is about 1,000 feet thick, and is mixed with chloritic and epidotic gravel, covering a space exceeding 10 square miles. In this region, and in the Eastern Townships, whole mountains are formed of serpentine marbles, of which abundant use could be made both for ornamental and building purposes; but although, on account of their richness and varied colouring and their capability of taking a high polish, few stones surpass some of the varieties of serpentine for decorative purposes, yet they are more fitted for indoor than for outdoor decoration because, being easily acted on by hydrochloric and sulphuric acids, they are liable to decay and to speedily become tarnished superficially; consequently they are not to be recommended for outdoor use in the smoky gaseous atmosphere of cities.

Sir William Logan says: "Les serpentines, dans toute l'étendue de leur gisement, fournissent de très beaux marbres vert-de-mer souvent ressemblant au vert antique."

Jaspers of very brilllant colours, yellow, red and green, called Gaspé pebbles, are found in the Gaspé limestones.

CHAPTER V.

THE CANADIAN MINES OR QUARRIES.

THE THETFORD GROUP—Discovery—The Johnson Mine—Boston Packing Company—Bell's Asbestos Company—Ward's Mine—King's—Quality of Thetford Ore—Western Limit Theory Exploded—THE COLERAINE AND BLACK LAKE GROUP—Anglo-Canadian Company—Scottish Canadian Asbestos Company—Frechette's Mine, now the United Asbestos Company's—Bell's—Wertheim's—Megantic Mine—White's Asbestos Company—Broughton—Soapstone—Danville—South Ham—Antimony—Wolfestown—Profitable Nature of Asbestos Mining.

The Thetford Group.—Notwithstanding that the existence of asbestos in Canada, especially in the province of Quebec, had been known to scientists long before 1877, it was not until the autumn of that year that a mine of any importance was opened. The building of the line of the Quebec Central Railway, across the serpentine belt at Thetford and Coleraine, was the approximate cause of the discovery. It fell to the lot of an agriculturist, named Fecteau, to light upon the mineral which has since had such an important influence on the welfare of the district. The accidental knocking off of a fragment of rock, and the consequent exposure of a vein of chrysotile, would be sufficient to strike any man with wonderment, and set him on inquiry. When exhibited, experts at once pronounced the quality to be good, and their statement, that asbestos of so fine a quality had never yet been found anywhere in the country, was abundantly justified on further examination; and, true to its early reputation thus gained, Thetford has continued to be the headquarters of the industry

and the main source of supply ever since. But if her reputation is to continue much longer, a better and more careful system of mining must soon be inaugurated, and means must be found of getting rid of the enormous piles of refuse now mounting up about the mines to dangerous heights.

Following on Fecteau's discovery, the first mine was opened here, by Messrs. Johnson & Ward. The demand for its produce was, at first, so limited that some difficulty was experienced in finding a market for the first year's output, which only amounted to 50 tons. The demand, however, rapidly increased, and the value of the mineral being soon recognised, active exploration was at once prosecuted in the immediate neighbourhood, and new companies quickly secured possession, at nominal prices, of the rocky tracts adjoining, and set to work opening up fresh mines. Asbestos of good quality was soon afterwards found to be distributed over a considerable area of the district. The four Thetford mines, which until very recently formed the Thetford group, were all located on a knoll, or mound, close by the line of railway, and rising 80 or 90 feet above the track. This knoll is now rapidly disappearing under pressure of work, and in its place enormous piles of refuse rock are daily mounting up on all sides, which disfigure the country, just like the hideous mounds of slag in the black country in England.

The Johnson Mine (*Johnson Asbestos Mining Company*) was the first mine opened on the knoll. This is situated on Lot 27 of the 6th Range of Thetford. Of this company the Hon. George Irvine, Q.C., of Quebec, is president, and Mr. Andrew Johnson, resident manager. In its main features this mine is very similar to the other three. The formation here consists of a massive serpentine, which varies in colour from a dark green to nearly white; this is intersected by numerous veins of asbestos, the fibre of which is singularly free from any admixture of foreign substances. When first opened, a trench about 50 yards long was cut, exposing a wedge-shaped mass of feldspathic rock in the serpentine. From the opening, the mine has been very successfully worked, and its produce has

always been regarded as second to none in the district. The output, in 1886, was approximately 375 tons, and the total produce up to the end of that year amounted to 2,500 tons; since which time it has continued rapidly to increase, and the quality of the fibre to improve, nearly the whole of the latter now being classed as No. 1. The returns for 1889 were not sent in in time to be included in the Government Report, but it is well known that the result of the year's work was very satisfactory.

The Boston Company's Mine (*now Bell's*).—Alongside the last-named mine is one which formerly belonged to the Boston Asbestos Packing Company, but is now the property of the Bell's Asbestos Company, Limited, of London. Of this, Mr. Thomas Sheridan has long been the resident manager, and, under his skilful guidance, the mine has always borne a very high reputation, both on account of the manner in which the work is carried on, and of the excellent way in which the ore is prepared for sale. This mine is on the same level as the Johnson, and the produce is of a very similar character, some of the veins disclosed being of an exceptional width of fibre, and the whole of the produce remarkably good. In a pamphlet published some short time back by the Canadian Government on the Mineral Resources of Canada, it was stated that the yield of this, and the Johnson Mine, had been pronounced by European manufacturers to be the finest and strongest fibre known, and that there *was no question at all of the profitable nature of asbestos mining in this belt of country;* a fact which has never been disputed by anyone who has watched the operations carried on.

The Boston Mine is of about equal extent with the Johnson, covering about 100 acres. It changed hands in the spring of 1888, on the formation of the Bell's Asbestos Company, Limited, which was formed in London to acquire the option of purchasing this mine, with 100 acres of land at Coleraine, and Mr. Bell's property, of about 700 acres, at Belmina, Wolfestown. The prices paid for these properties, as given in the

prospectus, are worth recording. These are stated to have been £41,300 for the Boston Mine, £8,000 for the 100 acres at Coleraine (part of the Reed & Hayden property), and £8,394 for the Belmina land. As soon as the purchase was completed, a steam plant was put down at Thetford, and very energetic work prosecuted, the difference effected by the change from hand labour to steam power being very quickly shown, by the increased output, which rose (for the season of 1888) to 1,350 tons. In 1889 the produce increased to 1,800 tons, of which the classification was as follows :—

No. 1	1,200 tons.
,, 2	200 ,,
,, 3	400 ,,
	1,800 tons.

The evil effects of the early dumping arrangements, and the want of technical or engineering knowledge displayed in laying out the mine, are here eminently conspicuous, although the same remark may, in some measure, be made as to all the mines laid out in the early days of the search for asbestos. The depth reached in the excavation here is greater than that at any of the other mines, and the practice has all along been to dump the waste rock on to the land immediately surrounding the opening. The consequence is that the surrounding hills of refuse are towering up higher and higher, in such a formidable way that it is much to be feared that, in the near future, the work will perforce be brought to a stand, unless means are devised of removing this waste.

The produce of this and of the adjoining mine, as already noted, is practically No. 1, which is a noteworthy feature of the Thetford mines. Occasionally there is a proportion of waste, but this is now waste only in name, as all of it can be sold. An attempt was made here recently by Mr. Sheridan to test the value of the rock at a lower depth, when the trial boring proved very successful, veins of a beautiful silky nature,

some three inches in width, being brought up from about 30 feet below the present level; the expenses of the shaft being much more than repaid, according to Dr. Ells, by the quantity of asbestos removed.*

The Ward and Ross Mine (*Thetford Asbestos Mining Company*).—This mine, situate on the south half of Lot 27, 5th Range, is of more recent date than the last. It is worked by the Brothers Ward, being owned by them conjointly with the representative of the late Hon. James Ross, of Quebec. The property comprises a little over 100 acres, and is not quite so advantageously situated for work as those already described, being on a lower level; it, however, turns out very good material. The output for 1886 was returned at 150 tons, probably at that time a fair average of what was being done. The figures for 1888 and 1889 were not sent in in time for the Government Report, so cannot be given here, but there is no doubt that under the stimulus of the high prices lately ruling the output has been very considerably increased. The same gentlemen have recently opened ground on the other side of the railway, between the line and the river. Here also good ore has been found, and the operations are likely to be carried on with success, but being on a lower level it is probable they will be much troubled with water, and that continual pumping will be necessary. When last at Thetford I saw some good ore on this land, which appeared to be of a very promising character; and notwithstanding the low level of the ground, which must necessarily add to the cost of mining, the size and quality of the veins are in no degree inferior.

King's (*The Hampden Mine*).—The only other mine here is that owned and worked by Messrs. King. This is situate on Lot 26, in the 5th and 6th Ranges. It bears much the same character as those already described; its produce having a high reputation on account of the careful way in which the ore is cobbed and prepared for the market, which is in marked contrast with the work done at one of the mines in the adjoining township. The output for 1888 was given as 580 tons, being

* Second Report for 1889.

a considerable increase upon that of the previous year. This was classed as—

No. 1	. . . . .	170 tons.
„ 2	. . . . .	165 „
„ 3	. . . . .	245 „
		580 tons.

This large proportion of Nos. 2 and 3 was due to the opening up of fresh land, the general produce of the grading being in no way inferior to that of the other mines. The average number of men and boys employed to get out and prepare this quantity was 32 men and 20 boys, but as the number of working days is not given the information is not of much value.

In his Report for 1889, the Commissioner of Crown Lands states that "MM. King frères, en outre de leur mine du Lot 5, 26 de Thetford, ont travaillé avec succès sur les terrains bas du Lot 5, 28 (*Thetford Royal Mine*), où la même qualité d'amiante a été trouvée." These four mines at present form the Thetford group, and as they were the first opened, so they are now by far the most important.

Two other mines have since been opened here, one by Messrs. Lucke & Mitchell, of Sherbrooke, and the other by Messrs. Murphy & Co., Montreal, both of which are shortly expected to show good results, especially the first named, although the last has apparently struck some rich ground.

The Thetford mines are at a lower level, and are worked at a greater depth than those of Coleraine and Black Lake, and probably for this reason the general output is of a more uniform character, and does not require such close classification. Nos. 1 and 3 are the practical grades, most of the produce being available for No. 1. No. 3 is a very inferior kind, merely the refuse, which, until the recent rise in prices, was sold and shipped in bulk at $10 per ton; but this is now more carefully looked after, as it fetches a paying price, and is in considerable demand for cement and similar purposes. The low-lying ground between the railway and the river has been proved in various places, but, although good ore has been found

here, it does not generally present so promising an appearance as that on the knoll.

In the summer of 1889, the belt of serpentine was uncovered by Dr. Reed on Lots 16, 17, and 18 (600 acres) in Range 4 of Thetford, and, although only a limited amount of work was done, a large number of veins of exceptionally good quality were disclosed. Indeed, all the mineral found in this locality is of excellent quality; the fibre is clear and fine and easily worked; the veins generally, especially those in the lower cuts, being comparatively free from chromic iron and other impurities, and of a width ranging from three-quarters of an inch to four and even six inches. Experience, however, has shown, as before stated, that veins ranging from one and a half to two inches give as good material as can be desired.

When the Thetford mines were first opened, the veins were often found to be cut or charged with grains and threads of chromic iron or of magnetite, the latter sometimes forming conspicuous masses between, and occasionally entirely replacing, the veins. But as the work progressed this intrusion of foreign matter gradually became less troublesome. As a general rule, however, the upper veins at Thetford have been found nearly as pure as those lying deeper in the rock.

Here as elsewhere faults are of frequent occurrence; and sometimes sheets of imperfect or immature asbestos, having a long, coarse, woody fibre, are to be met with lying all along the sides of the fault.

The Thetford mine owners are always ready to give every information about their work, and willing to facilitate an inspection of their mines by any one taking the trouble to visit them, a trouble I found very amply repaid by the courtesy with which I was always received, and the candour and obliging readiness with which all my inquiries were answered.

The workers are mostly resident on the spot, the proprietors appearing to act in a spirit of liberal consideration towards them, doubtless finding the advantage of looking after the welfare of their men by not running short of hands at critical times.

The Quebec Central Railway runs right through the town, where there is a commodious station facing the mines. On stepping out of the train the mines are seen all together in front of the platform, and as the train moves on, the rail has only to be crossed to reach them. At the rear, that is, divided from the mines by the line, are the dwellings of the workmen, at either end of the place being two houses of a superior class, belonging to two of the principal mine-owners, and in the remoter background the Thetford river rolls sluggishly along.

This river, until quite recently, was believed to mark the western limit of the asbestos-bearing serpentine, the rocks on either side being mostly altered slates and sandstones; but the existence of valuable deposits of the mineral on the further side has now been amply proved. To the east, or fronting the railway, the serpentine forms a knoll which has an elevation of 80 or 90 feet above the line of rails, and it is upon this knoll that the present mines are all being worked, and which they are rapidly cutting away. Until very recently but little had been done to ascertain the value of the ground between the rail and the river. Although the ground is low hereabouts, there are certainly good indications of asbestos; and as mentioned above, some very promising looking ground has recently been opened up by the Messrs. Ward, sufficiently proving the prolongation of the serpentine area between the present workings and the river. Further west, and nearer the river, both Messrs. King and the Johnson Company have since opened ground which has proved highly satisfactory as regards quality and quantity of fibre.

The uniform practice, at all the Thetford mines, hitherto, has been to close down entirely for the four winter months, it not having been found sufficiently lucrative to encounter the additional expense of winter work in the open, the difficulty being then materially enhanced by the rigorous weather and heavy snowfalls. Now, however, the great rise in the price of crude ore, and the increasing demand for it, have caused attempts to be made to carry on the work through the winter season on a

reduced scale, but it is doubtful whether this can be done with more than a limited amount of success.

Chromic iron is found in this area, but the quality is not rich. Veins of a soft white mineral are also found here, which hardens on exposure to the air; but, unlike the soft serpentine found in the Megantic Mine (*post*, p. 102), this does not acquire a waxy lustre, but has much the appearance of unglazed white earthenware, and absorbs water with avidity.

On analysis its composition was found to be—

Silica	43·191
Alumina	1·463
Ferrous oxide	·293
Magnesia	41·520
Water	14·000
	100·467*

The fibre from the Thetford mines differs a good deal from that obtained elsewhere. That from Coleraine and Wolfe is to some extent affected by harshness and a want of elasticity which causes the percentage of No. 1 from these two districts to be less than at Thetford. The fibre is also mostly shorter in staple, and much of it is discoloured by the infiltration of water impregnated with iron.

As already mentioned, great mistakes were made, here as well as elsewhere, when the mines were first opened, arising mainly from inexperience and want of the knowledge now possessed, which will inevitably entail serious loss in the future, much valuable ground being now covered by the dumps which will unquestionably have to be moved when the land is wanted for working, the cost of which will be enormous. Moreover, these mines, being located on ground which, excepting the knoll now fast disappearing, forms a level plain, the clearing of the pits and the removal of the ore and waste rock will always be a troublesome and expensive task.

The same want of foresight in selecting proper dumping

* J. T. Donald, Esq, M A., Montreal.

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SURFACE VEINS AND OUTCROPPINGS.

ground, for which there was less excuse with the Thetford experience to guide them, will inevitably cause trouble in the near future at Black Lake, even to a more serious extent. The parties who first opened up the ground there evidently knew what they were about, but their immediate successors, being destitute of all practical mining knowledge, have, by their neglect of professional assistance, committed errors of judgment such as will presently occasion very serious expense. At one of the main pits many thousands of tons of waste rock have been dumped on to some of the richest of the ground, and this must be again moved before that ground can be worked. From the peculiarity of the work, there probably exists no class of mining which so absolutely necessitates the services of a practical mining engineer, to mark out the land in the first instance for mining and dumping, as that for asbestos does.

During the visit of the American Institute of Mining Engineers, in the autumn of 1889, these defects caused considerable remark, and many suggestions were made as to the desirability of putting matters on a different footing for the future working of the mines.

The cost of extraction of the ore varies in different localities, depending mainly on the mass of barren rock to be removed, which, owing to the action of faults, is greater in some places than in others. At Thetford it may be put at from $20 to $25 per ton, the latter being probably nearer the average, except at the Boston Mine, where the machinery employed reduces the cost to about $15.

The Coleraine and Black Lake Group.

The mines grouped about this district are next in importance to those last described; but, although the distance from Thetford is only four miles, there is a very perceptible change observable in the face of the country. The rock formation alters as the station is approached, and when Black Lake is reached you are at once face to face with the grim and rugged-

looking hills which rise somewhat precipitously, from the shore of the Lake, to a height of 600 or 700 feet, and form the beginning of the bare and cheerless-looking district of Coleraine. There is but little soil here to cover the rocks, and often, as is quite apparent, after the first growth of timber which covered these hills when in a state of nature, had been cut, the undergrowth was destroyed by forest fires, and then the comparatively thin layer of soil having been washed away by the rains, the bare and sterile rocks are left exposed to view. This is a far more likely-looking country for the prospector than that about Thetford; but, although good ore is abundant throughout the district, it does not, as a rule, come up to the standard of the latter place. The quality of the ore is found to have perceptibly changed, becoming, especially in the upper veins, coarser and more brittle; in places also there is more depth of soil, and the rock is a good deal shattered and occasionally decomposed by weathering, offering more facility for the infiltration of surface water, which, being a good deal impregnated with metallic oxides, detrimentally affects the value of the fibre by discolouring it.

Owing to the destruction of the forest over the knolls of serpentine by bush fires, to the action of the weather, or to the intrusion of masses of granulite, the fibre here is frequently harsh and brittle, especially near the surface, changing, however, to greater silkiness as the veins are opened out deeper in the solid rock. This peculiarity has given rise to a good deal of speculation, and various causes have been surmised to account for it: difference of level, for instance, the forest fires, or the granulite, which is here abundant, and the heat from which on its eruption would have a tendency to dissipate a certain proportion of the contained water in the chrysotile, in the same way as the forest fires, though on a more extended scale. Mr. Donald has shown that harsh and brittle kinds of chrysotile contain less water than the softer kinds; in very flexible fibre he found 14·05 per cent., whilst in a harsh-fibred sample there was only 12·62. The same effect can be produced by placing a piece of the ore on a sufficiently heated surface,

when the fibre will be found in a very short time to have lost its softness and flexibility, and to have become harsh and brittle,* and in this state it may often be crumbled between the fingers. The writer has frequently seen boxes of ore brought into the cobbing-shed after a wet night, when the men would at once set to work to pile it up round about the stove, so as to dry it somewhat before cobbing, when that which was placed nearest to the stove, or possibly kept there too long, would gradually become changed, and present the harsh and rough features mentioned.

If the aqueous origin of asbestos be admitted, it seems reasonable to suppose that all the fibre, when first deposited, was soft and flexible, containing a maximum amount of water, and that movements of the rocks, producing heat, have driven off a portion of the water of the contained asbestos and thereby destroyed the softness of the original fibre. Veins at considerable depths may have been subjected to the heat produced by these movements, and yet not deprived of any portion of their original water, because of the resistance of overlying rocks.†

The granulite referred to above is of a greyish-white colour, and mainly consists of orthoclase feldspar and quartz, which is thrown up after the manner of dykes. Near the contact with this, the serpentine is often considerably shattered, as though the presence of the granulite had exercised a marked effect on its condition. At Thetford, the intrusive rocks in the mines are limited to small and thin dyke-like veins, which do not appear to have produced any marked effect on the ore; but here the granulite forms masses of a much greater size, and these have produced a correspondingly greater effect. Dr. Ells, however, truly remarks that the stiff-fibred mineral is not in all cases confined to the vicinity of the granitic masses, and consequently it is just possible that other causes may have tended to produce a similar effect. It is scarcely likely that the difference in level can have anything to do with the change in quality of the ore, because the operations of the Scottish Canadian Com-

* Dr. Ells on the "Mining Industries of Eastern Quebec," 9.

† J. T. Donald, *Canadian Record of Science*, April, 1890.

pany are carried on 300 feet higher than the Thetford mines, and Dr. Reed's mine (now Wertheim's) is 300 feet higher still, and in both these mines excellent fibre is found. The most likely cause is that of dehydration, caused by the intrusion of the heated masses of granulite when forced up from below.

In one of the granitic dykes, on the Scottish Canadian Company's property, Mr. Donald found scolecite * occurring in transparent glassy needles, filling minute veins, and in masses of white, grey, and colourless radiating fibres. This is believed to be the first zeolite found in the dykes cutting the serpentine here, and the first known to occur in Canada. Enstatite, conspicuous because of its bronze lustre, is also found in the serpentine here.

The Anglo-Canadian Asbestos Company.—The pioneer of the mines in this district, the next in importance to Thetford, was Mr. Noel, of Richmond, in the same province, who in 1881 opened a mine here, which he afterwards sold to Mr. Lionais. This mine was called the "Eureka," and soon afterwards Mr. Lionais opened another, which he named the "Emelie." The property, on which these two mines are located, subsequently came into the possession of the late Mr. Sénécal, and was by him transferred to the Anglo-Canadian Company on its formation in London by Baron Grant in the autumn of 1885.

The estate comprises something over 300 acres. The output for 1886 was stated by Dr. Ells in his report to the Government to have amounted, according to information given him at the mines, to 550 tons. This was so manifestly exaggerated that, after the report was in type, the error was rectified by giving the correct figures obtained from Captain Evans, who certified the quantity to be 330 tons.

The output for 1889 was returned at 630 tons, with an improvement in quality, the percentage of No. 1, according to the manager's statement, having increased from 10 to nearly 20 per cent.; but even this large output proved of no benefit

* From σκωληξ, a worm, in allusion to its action when heated before the blowpipe, when it will curl up in worm-like fashion.

to the shareholders, as the company went into liquidation at the close of the season. It has since been reconstituted on the footing of a surrender of the old shares on which £2 per share had been paid, and the issue in exchange of £1 shares, on which 17s. 6d. was credited as paid, the remaining 2s. 6d. per share being paid up in cash.

The Scottish Canadian Asbestos Company.—A few minutes' walk across the hillside brings us to the property on which the Martin Mine is located. Here we find broad, well-made roads traversing the property, well-built premises, and the business of the place, when I last visited the spot, was proceeding with intelligent regularity. Unfortunately, this company has also, since then, gone into liquidation, but from altogether different causes, the whole of its capital having been expended, under previous management, in a too lavish outlay for machinery, railway tracks and buildings before work was properly established. The property is a good one, and will no doubt presently show adequate results. At the time of my visit the Martin Mine had only been recently acquired by the Scottish Company, with the intention of working it in conjunction with their property at Broughton.

This company's land lies in the form of a parallelogram, and covers somewhat more than 100 acres. Towards the north and along the northern boundary the ground rises to about 100 feet above the level of the railway, which is distant about a quarter of a mile. To the south-east the hills, mainly composed of talc and mica schists, increase in elevation until, at a distance of about 1,800 feet from the railway, it attains a height of 900 feet above the level of Black Lake. At this point the serpentine formation begins, forming a ridge 300 feet higher than the highest point of the shales. The serpentine belt crosses the company's property east and west, and is bounded along its northern margin by a mass of quartzose granulite, which is here separated from the serpentine by a narrow band of steatite. The mine is fully equipped with powerful machinery, and a new set of appliances for crushing

and separating the lower grades of ore, which, as we have already seen, are very considerable in all the Black Lake mines, as well as to save the expense of hand cobbing. In 1888 the production here had risen to 400 tons, of which amount 40 tons were No. 1, 110 tons No. 2, and 250 tons No. 3. Since then the mines have much improved, and the output also, until the stoppage of work.

The developments of the Martin Mine consist of an excavation on the hillside 225 feet long by 100 wide. The lowest level of the quarry, at the time of my last visit, was about 80 or 100 feet below the highest point of the profile of the mountain (now much lower) and communicated with the dumping-ground by a cut through the granulite and soapstone.

Another quarry opened on the same property is called the "Bonanza." Both quarries are, from their position, well drained, and free from the water which is so great a trouble at the last-named works. The houses for the manager and workmen, stores, factories, stables, and workshops form groups on the hillside, and give a cheerful appearance to this part of the country.

The Frechette-Douville Mine is located on a narrow strip of land running up the hillside, and comprises about 95 acres. It is bounded throughout its whole length by the property of the Scottish Canadian Company on the one side, and that of the Anglo-Canadian Company on the other. Work has lately been very energetically prosecuted here, and some very good material obtained. The mine has now been sold to the United Asbestos Company, of London, who have placed it under the management of Mr. Penhale, Junior, formerly of the Scottish Company. A good steam plant has been laid down, consisting of two 70 horse-power boilers, duplex 7 by 10 inches Bacon hoist, and a 16 by 24 Rand compressor. The equipment of steam derricks, air compressors, drills, &c., was put in by the Tenckes Machine Company, of Sherbrooke. A force of about 35 men is employed and work will be very energetically pushed on this season. A new opening, now being worked, shows some very excellent

fibre. The exports to the United States from this mine in 1889 were :—

No. 1	165½ tons.
„ 2	62 „
„ 3	132¼ „
Waste	20 „
	379¾ tons.

The Southwark Mine is opened on the northern halves of Lots 27 and 28 on Range A, part of what was formerly known as the "Reed & Hayden" property; it comprises 100 acres of land, and formed part of the purchase of the Bell's Asbestos Company, Limited, as previously mentioned. Until quite recently it was under the charge of Mr. Calvin Carter, late of Belmina. The output of this mine to 30th June, 1889, is returned as 198 tons, but the comparative grades are not given.

The Wertheim (American Asbestos Company's) Mine occupies the southern halves of the two lots last mentioned, and was bought at the beginning of 1889 from Dr. Reed by Mr. Wertheim, asbestos manufacturer, of Frankfort-on-the-Maine, and transferred by him to a company formed in Germany, called The American Asbestos Company. A good steam plant was at once put in, and the work has been carried on with such energy and success, that this mine bids fair to turn out the best in the district. It is situate on part of the high ridge south-east of the Black Lake Station, and is at present the most elevated in the district, being about 600 feet above the level of Black Lake. A good many houses have been put up for the workmen, and many Belgian miners and their families have been taken over and located there. The machinery was ready to run at the end of July, and notwithstanding that work was impeded by an epidemic which soon after broke out among the workpeople, the output for the year ending 30th November last reached the satisfactory total of 530 tons, sufficient to pay a good dividend on the

capital employed. All the arrangements for working were good, the plant judiciously selected, and in the result fine veins of very soft and silky fibre were opened.

A new departure has been taken here; in order to facilitate the development of the mine, a tunnel was run in from below under the No. 2 and 3 pits, whence a shaft was cut for 100 feet to reach No. 2. This tunnel is 6 feet by 6, and both the tunnel and shaft run the whole distance through asbestos-bearing rock, all pumping being thus obviated, and a splendid working face formed.

During the first six months of the year hand labour only was employed, after which steam plant was put in operation. The mining figures for the first year are worth recording; these were :—

No. 1	79¼ tons.
,, 2	81¼ ,,
,, 3	357¾ ,,
Hornblende	12 ,,
	530¼ tons.

Reed's Mine.—On the north side of the Poudrier road, on Lots 27, 28, and 29, Range A, work has been commenced by Dr. Reed, by clearing the ground and opening up, so as to show the quality of the ore: some good veins have been disclosed and are now open to view. In the spring of 1890 active work was commenced here by the owner, about thirty men being employed on contract, with highly satisfactory results.

Between these properties and Cariboo Lake the serpentine extends in a continuous ridge, and shows at intervals very good indications of asbestos. This area, however, has not yet been sufficiently explored for much to be said, from actual observation, of its value as asbestos land, though it seems reasonable enough to suppose that this portion of the serpentine belt will presently be found equally valuable with that of the adjoining section.

Mr. Obalski, who has examined the ground, states that the

whole mountain is formed of rich asbestos rock, a careful inspection of the summit of the mountain, as well as its base below the road, giving the same indications, the asbestos everywhere showing at the surface in veins sometimes 2½ inches broad.

Megantic Mine.—On again entering the train and progressing towards Coleraine, serpentine is found to occur near the station, but the main ridge of the rock, extending south-west, keeps to the north-west for about a mile and a half, where it forms a conspicuous hill feature. An opening made on this south-west extremity some time ago, by Mr. Kennedy, disclosed a number of asbestos veins, one of which had a width of nearly four inches. In 1888 preparatory work only was carried on, but the result was sufficiently satisfactory to justify active operations. Dr. Ells reports for 1889 as follows:—"The rock here is very much shattered near the surface and the fibre is consequently discoloured. Veins up to one inch and a half are found and in the more solid portions the quality improves. The output from this place has been necessarily small, owing to the time spent in opening the mine, and the delays from bad weather, the quantity mined in four months, to October 1st, being 39 tons, of which one third may be classed as No. 2, the rest as No. 3. An average number of twelve men was employed."

In the immediate neighbourhood of this last mine, operations have been commenced by Messrs. Lambley & Co., of Inverness, some good veins being met with at the top of the hill.

Mining in this locality was commenced in 1886, when the four-inch vein was found not to be persistent for any depth, the rock being greatly shattered near the surface and for about 15 feet down, and though a great many veins were found, some of them in the solid rock, much of the fibre was discoloured. A peculiar feature here, which has not been observed in any other of the mines of this district, is the presence of irregular veins of mica, in scales of an inch or more in diameter, in a paste of decomposed serpentine or soapstone.*

* Dr. Ells, Second Report, 1888.

There is also a singular form of serpentine which occurs here in narrow seams, so soft that it may be compressed between thumb and finger, and varying in colour through white, blue, green, and yellow; when exposed to the air it becomes hard and assumes a waxy lustre.*

On the same ridge, but on the extreme west limits of Lots 24 and 25, Range 3, Ireland, Messrs. King Brothers have started two openings. The elevation of these by aneroid above the level of Black Lake is 500 feet. The asbestos found here is principally met with in two knolls lying about a quarter of a mile apart. Many of the veins show a selvage of white weathering serpentine, separated by a vein of asbestos from a quarter to three-quarters of an inch in width. The general aspect of the rock and veins strongly resembles those found at Belmina, but the quality of the ore is much better and successful mining far more likely.

White's Asbestos Company.—In the spring of 1889, a company was formed in London, under this title, for working two lots of land in Coleraine and two others in Garthby, containing in the whole 372 acres. It is much to be feared that the ground was not judiciously selected and that no beneficial result will ensue. The Commissioner for Crown Lands reports, for the past year, that the company has done some prospecting work without obtaining any appreciable result.

These are the only mines at present being worked in the district, but from indications on other properties lying on the same line, there can be little doubt that others will presently be opened up in this locality. Capital is all that is wanting at present; but, as the demand for the mineral increases, the necessary capital for producing it in larger quantities will no doubt be forthcoming.

The cost of mining, for the reasons already given, must of necessity be greater at Black Lake than at Thetford, and cannot be put at less than $28 a ton. After removal of the surface earth and rock, the proportion of refuse rock is about 25 tons to one of asbestos.

* J. T. Donald, Esq., M.A.

The following very interesting comparative analyses of some of the ores of this part of the country have been furnished by Professor Donald, of M'Gill College, Montreal, who is making a special study of the mineral:—

	No. 1 Asbestos	No. 2 Asbestos	No. 3 Asbestos	No. 4 Asbestos	No. 5 Serpentine	No. 6 Picrolite
Silica . .	39·22	41·90	41·84	42·64	40·34	43·70
Magnesia . .	40·27	42·50	41·99	39·54	43·32	40·68
Alumina . .	3·64	·89	—	—	1·32	—
Ferrous oxide .	2·26	·69	2·23	3·66	1·23	3·51
Water . .	14·37	14·05	14·28	14·31	14·17	12·45

No. 1 is from the Southwark Mine, at Coleraine, the sample being classed as fair No. 1.

No. 2. Very fair quality ore from the Scottish Canadian Company's mine at Broughton.

Nos. 3 and 4. Asbestos from Mr. Jeffrey's mine, at Danville; analysis by Professor Smith, of Beloit College.

No. 5. Serpentine from Brompton Lake.

No. 6. Picrolite from Bolton; analysis by Dr. T. Sterry Hunt.

The special point to be noted here is the variation in alumina, ranging from 3.64 per cent. at Black Lake to none at all in Danville.

East Broughton.

The Frazer Mine.—In order to visit this mine it is now necessary again to take the train and return through Coleraine, Black Lake, and Thetford, after which the East Broughton station is soon reached, whence it is only a short drive to the mine, the road passing through a much more cheerful-looking country than that previously traversed. Broughton, which marks the extreme eastward limit of the asbestos region, so far as yet opened up, is in Beauce County, just outside the boundary of the Eastern Townships, and here the land is of a more pastoral character, with pleasing stretches of woodland scenery.

The Frazer Mine was first opened and worked by Dr. Reed

some few years ago. The discovery here made a great stir at the time, as no mine in Canada had then, or indeed has since, produced asbestos of quite the same quality; but, to all appearance, the big vein (there was only one) was soon worked out, the ore exhausted, and work in consequence discontinued. When first worked the vein was nearly a foot thick, and remarkable for the silky softness of the fibre. It was found at the contact of the serpentine with blackish slates, which in places have a greyish or purple shade, containing bands of hard bluish-grey quartzite of the Cambrian series, thickly veined with quartz. It is overlaid in places with soapstone of good quality, from 10 to 14 inches thick, with which the asbestos seems to be intimately associated. The vein had the general aspect of a well-defined vein with, in some places, a hanging wall of soapstone, and was worked for a distance of several hundred yards to a depth of about 70 feet. In the lower workings it was found rapidly to decrease in size, and ultimately it split up into minute strings which rendered it worthless.*

Although at some little distance from the station, the mine lies close to the rail. It is now the property of the Scottish Canadian Asbestos Company, and comprises 116 acres of freehold land, supplemented by mining rights extending over about 2,000 acres more. Large sums have been expended in laying out this property, perhaps too lavishly, and in buildings, factories, machinery of all kinds, tram lines, &c., the extravagant outlay being, doubtless, the cause of the company going into liquidation, which was a great misfortune for the district.

When I visited the mine, in the autumn of 1886, I went all over the ground with the late Mr. Frazer, but we were quite unable to trace any part of the big vein. Our search, however, was a good deal impeded by the depth of water in the cut, which prevented our making so complete an investigation as I could have wished.

The vein here was from 8 to 10 inches thick near the sur-

* Dr. Ells, on the "Mining Industries of Eastern Quebec," Second Report, 1888.

face, but decreased at the bottom of the workings, some 62 feet down, to two or three inches, and then it became irregular, splitting at times into many fine strings disseminated through the serpentine, at others presenting a continuous fibre. Three shafts were sunk to a depth of 61, 62, and 75 feet, which followed generally the slope of the bed or vein at an angle of about 75°, the rock dipping S. 40° E. to true meridian. The mass of serpentine, which lies to the west, was carefully examined at several points, but only in one place, about 150 feet in rear of the openings, were small strings of asbestos, of one-fourth to half an inch, seen. Much of the fibre in the north slope appeared to be stiff and harsh, while other portions were beautifully silky. The serpentine resembles in character that near St. Sylvester and along the Chaudière.*

The belt just here is very narrow, contracting in places to not more than 15 feet in width, the veins of asbestos being found closely compressed together. This imparts a certain regularity to the deposit, which up to this time has been observed nowhere else. Schists, talc, and serpentine are interstratified to a depth of from 8 to 10 feet, and the asbestos veins in the serpentine connect with and join each other, forming distinct leads, from 14 to 16 inches wide, occurring as congeries of divided or partitioned-off seams. There is less waste here than usual, but the breaking out of the rock is more difficult.

The Broughton ore has a pale yellowish green hue, as distinguished from the darker greenish metallic lustre which distinguishes the finer samples from Thetford, which is another peculiarity of this ore, the light-coloured serpentines being almost always barren everywhere else. The colour of the ore, however, in no way affects the clear whiteness of the fibre when crushed out, although it affords a means of identifying the locality of production. There are, in fact, as I have already mentioned, certain peculiarities, even of colour, attaching to the ore of each locality of so marked a character that an expert can at once tell, on inspection, from whence it was obtained.

The cost of extraction is put by Mr. Obalski at $35 per

* Second Report, 1888.

ton, which is caused by the peculiarity of stratification and the greater than usual difficulty of mining, and he is of opinion that the output will be certainly limited.

Operations were going on here and also at Coleraine, previous to the stoppage, for the utilisation of waste; the narrow veins of only a few lines in thickness usually passing as such, and being thrown on the dumps. There is certainly no reason why this should be so, because, if properly treated, these thin veins would pay for the trouble bestowed on their separation. Thousands of tons are annually wasted, much of which is as much due to careless work as to inefficient machinery; but this will no doubt be presently remedied as the mineral becomes more valuable and improved machinery is employed in its preparation for market.

There is great abundance of soapstone at Broughton, much of it of good quality, some remarkably pure, and some of it curious. I brought away with me a fine specimen, having all the grain and fibrous markings of asbestos, but pure and unmistakeable steatite. No use is made of this at present, all attention being devoted to the production of the higher-priced chrysotile.

DANVILLE.

At Shipton, about four miles from the village of Danville, there is another mine, lying contiguous to the Grand Trunk Railway, which has been worked, for some years, by Mr. Jeffrey. Time did not permit of a visit to this mine, consequently I can give no details of my own knowledge.

The property covers about 75 acres, the output of serpentine forming a knoll of somewhat limited extent, with steep sides all round it. Numerous veins of asbestos are found here, mostly of small size, seldom reaching two inches, but of good quality. Faults are numerous, which considerably affect the value of the mine; good veins of two inches being sometimes cut off completely at a distance of 50 feet from the surface. The output has, however, been considerable. For the year

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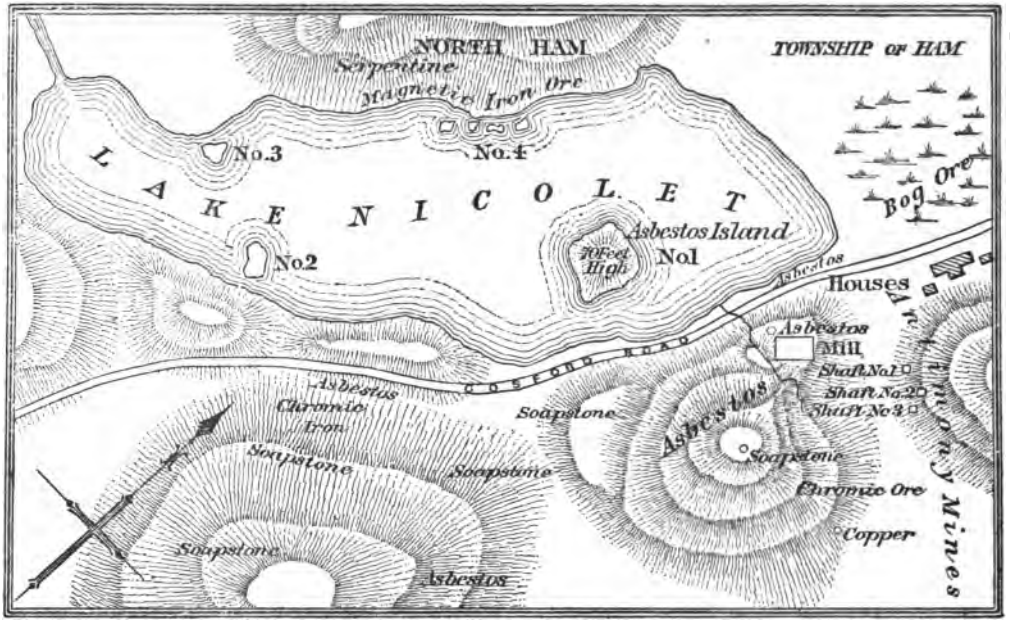

SKETCH MAP OF THE LAKE NICOLET ESTATE

ending 28th August, 1886, it was 455 tons; though, from some cause not explained, the output has since been less, the mine not being worked to its full capacity. The proportion of No. 1 grade here, according to Dr. Ells, is at present (1889) about 20 per cent., and of No. 2, 60 per cent., the remainder, of course, being No. 3 and waste, thus approximating closely to the output of the mines at Black Lake.*

Mr. Jeffrey has also found asbestos at Cleveland, where the mineral occurs in good massive serpentine, apparently forming a wide band, but not showing much on the surface.

South Ham.

The mines here, of which a rough sketch is shown, are situate on land known as the Nicolet Estate, in the township of South Ham, about 7½ miles from the Garthby Station of the Quebec Central Railway.

It was on a brilliant morning in the latter part of October, 1886, that I started from Black Lake, where I was then residing, to visit Nicolet, on the invitation of the owner. There had been a sharp frost in the night, forerunner, as it proved, of an early and severe winter; but when the sun rose the air was delightfully crisp and invigorating. A quick run on the rails took us to Garthby, a characteristic Canadian settlement, pleasantly situated on the shores of Lake Weedon. The view over the lake, with its background of timber-clad hills, bathed in brilliant sunshine, was very charming; but as that was not what we had come out to see, we had to mount our buggy and start off at once, for a drive over a rough mountain road, in order to reach our destination before evening set in.

On arrival, we went straight on to examine the owner's antimony mines, to which he was then devoting his whole attention, he being satisfied with knowing that asbestos existed in abundance on the property, leaving its exploration for a

* Dr. Ells, "The Mining Industries of Eastern Quebec," October, 1889.

future day; but as it is that mineral only with which we are now concerned, we will reverse the operation.

The asbestos deposit here was first discovered on what is called Big Island, being the largest of seven islands ornamenting the sheet of water called Lake Nicolet. The serpentine rock which forms Big Island, rises very abruptly out of the water to the height of 70 feet, forming, on the western side precipitous cliffs, the whole of which is seamed with asbestos; recent exploration, however, has shown that the main body of the mineral, passing under the lake, occurs on the hillside, and is of such extent as altogether to eclipse that proved to exist on the island, which was at first thought to be the chief source of supply.

The mine on the island is not being worked, but has been fully proved by numerous openings which have been made at the most promising points, revealing in every case veins of asbestos of remarkably good quality and in great abundance. These pass under the lake, and can be seen cropping out in many places, off the shore and on the hillside.

The mineral as seen on the island presents many points of difference from that at Thetford and Coleraine; and in the Geological Survey of Canada, written many years ago, it is stated to consist of four varieties, viz. :—

1st. Small veins, rarely exceeding half an inch in width, the fibres not easily separable. This, however, does not detract from its commercial value.

2nd. Apparently occupying a position at right angles to the veins above noticed, is a coarse fibrous mineral, resembling rope, and evidently derived from the associated picrolite. The extreme length which these fibres may attain could not be determined, but judging from exposed portions, it cannot be less than three feet.

3rd. Veins somewhat resembling the latter in aspect, but much finer in texture. The fibre can be separated with great facility, though firmly attached at one end to the parent rock.

4th. A steatitic asbestos rock, resembling "Mountain lea-

ther," forming important masses, which enclose small concretionary pellets of asbestos, the centres of which contain a nucleus of serpentine.

Very little (the report says) has yet been done on the island to develop these asbestos veins, perhaps owing to the difficulty of transport across the lake. *This, however, would probably be more than counterbalanced by the magnificent returns which this locality promises to afford.**

There could, however, be no practical difficulty in arranging this question of transport; but when mining for asbestos is undertaken here, there will be but little temptation to commence operations on the island, as the deposits on the mainland (which were not known to exist, at the date of Mr. Willimott's visit) will furnish abundant scope for energetic work for many years to come.

The temptation to describe the scenery round the lake is very great, but as that does not fall within the scope of the present work, it must be sufficient to say that it is of a very charming character.

The estate itself might very justly be termed unique for mineral riches, for, comprised within its 2,000 acres, are found not only rich veins of antimony and asbestos, but enormous deposits of steatite, magnetic iron, chromic iron and bog-ore, as well as copper and sulphur, and it is believed both nickel and cobalt. Silver to the value of $4 a ton is found with the antimony, and reefs of auriferous quartz run through the entire property, a sample from which, on assay, gave 2½ oz. gold to the ton.†

The Commissioner of Crown Lands in his report for 1889, says that the antimony mines have not recently been worked, except in the way of exploration, which has led to the discovery of many new veins. Since then a considerable amount of work has been done, an adit, from the bottom of the

* Willimott's Report (1882) on some of the mines in the province of Quebec.

† Report of the Committee appointed by the Dominion Government to investigate the Gold Fields of Canada.

hill, effectually drains the mines and some very fine veins have been disclosed, including much native antimony. Some fine crystals of Senarmontite* have also been found here. It is also worthy of note that Professor Dana, in his "Descriptive Mineralogy" (1877), instances these mines amongst the few places in the world where veins of antimony occur. Some singularly fine specimens of native antimony, kermesite, stibnite, and valentinite† from these mines, shown at the late Colonial and Indian Exhibition, for which a medal and diploma were awarded, are now in the charge of the Canadian authorities in London, having been presented by Dr. Reed to the Imperial Institute. These will be found specified in Dr. Selwyn's "Descriptive Catalogue of the Economic Minerals of Canada, 1886."

Everything necessary for the working of these valuable deposits already exists on the ground—unlimited water supply, and timber for building and mining purposes, as well as for charcoal for any furnaces that may presently be erected; sufficient, if judiciously managed according to the rules of forestry as practised in Germany, Austria, and Russia, to last until a new growth matures. In regard to transport, the roads are good, and a line of rail connecting the Grand Trunk with the Intercolonial will presently touch the property, and will, it is expected, have a station there just below the antimony mine. In regard to steatite, the quantity here is so enormous that an expert, lately sent to report on this property, speaking of the steatite, says, "All I can say is, there are mountains of it."

Wolfestown.

The description of the asbestos area of Wolfestown is given by Dr. Ells. It is situate on the north-east extremity of a serpentine ridge which extends south-westerly, with many

* The isomorphous sesquioxide of antimony.

† Valentinite, with the same chemical composition as Senarmontite, differs from the latter in crystallisation.

interruptions, from the road leading from Coleraine Station to Wolfestown, in the vicinity of Lake Nicolet.

The Belmina Estate, distant about four miles from the railway station at Coleraine, comprises about 700 acres, and as already stated, was formerly the property of Mr. John Bell, and by him transferred to the Bell's Asbestos Company, on its formation in London, in 1888, for the sum of £8,394. The surface indications here are said not to be equal to those at Black Lake, but at several points numbers of veins are shown, some of which are from one and a half to two inches thick. A very fair showing of workable veins has been exposed on the upper part of a deep cut, which it is proposed to intersect at a considerably lower level. Should the same rule of increase which holds good at Thetford and Coleraine apply here, there should be good paying ground exposed when the lower level is driven in past the cap of barren rock, provided the veins already disclosed are not cut off by faults, whose presence is noted here as at other points.

Late in the autumn of 1889, operations were announced as about to be commenced by some capitalists of Montreal on property acquired by them near Brompton Lake, where deposits of asbestos exist; a very fine sample of which has just reached me.

The foregoing comprise all the Canadian mines now in work. There can be no doubt, however, that new mines will presently be opened. At this moment, supply by no means keeps pace with demand; manufacturers are consequently unable to obtain the ore they are perfectly willing to pay high prices for, the prices charged now closely approaching the prohibitive; active steps are therefore being taken all over the serpentine belt for the discovery of fresh mines, but until these are discovered and get to work it is abundantly clear there will be no drop in prices. *Long before this state of things had occurred it was conclusively proved that mining for asbestos, properly conducted, shows a more steady return for the money invested, with less elements of risk, than mining for any other known mineral.*

CHAPTER VI.

OUTPUT, COST OF PRODUCTION, WAGES, ETC.

Rapid Advance of the Industry—Upward Tendency of Prices—Progressive Output—America the Largest Consumer—Commissioner's Report for 1889—Percentage of Output—Old Methods of Work discontinued—Cost of Cobbing—French Canadian Labour—Drink—Points for Consideration—Causes of Failure.

The exploitation of asbestos in Canada has been making rapid strides from the date of the discovery of the Thetford deposits in 1877; but even now, more than twelve years later, viewed in the light of its possibilities, the manufacturing industry in England is but in its infancy. For the first ten years after the discovery, that is, down to 1887, the price of the crude ore had been gradually increasing in correspondence with the demand, with some, but by no means a proportionate, augmentation of the supply. In that year, however, several new quarries were opened, many buildings were erected, including two factories for the manipulation of the crude ore on the spot, and one of the companies built a branch line of railway to connect their works with the main line; the general result of the year's progress being such as to make it clear, that the industry was assuming such proportions that in the near future it would be the most important, as it already was the most remunerative, in the Province.

Satisfactory to the producers as was the result of 1887, still greater progress was made in 1888, and from the returns for 1889, just issued, it is seen that a yet greater leap forward has been taken. The extraordinary rise in prices which took place

in the autumn of last year, and which still goes on, is a natural consequence of the fact that, notwithstanding every effort, the mine-owners find themselves unable to fulfil contracts; the supply for the past year, although considerably in excess of any previous output, not sufficing to keep pace with the ever-increasing demand.

Until, therefore, fresh mines are opened, or other discoveries made, it is clear that this upward tendency of prices must continue to go on; probably, this will not so much affect the manufacture of the higher class of spun goods, as it will materially limit that of such materials as felts, sheathings, and carpet or partition linings, &c. One unexpected result of the unusually high prices has, however, been to drive all the more important manufacturers into the market to buy mines for themselves, and so to turn producers as well as consumers, in order that, by employing more scientific methods of work and improved machinery, they may raise for themselves such supplies of ore as day by day it becomes more difficult for them to obtain through the ordinary trade channels. This, again, has the effect of driving prices up still higher, because the produce of the mines so purchased is practically withdrawn from the general market, the new mine-owners requiring for their own factories all the ore they can raise. Unusual efforts are, consequently, now being made over the whole of the productive areas to find and open up new mines, fresh capital is being continually brought in, whilst new developments of the industry are as constantly preparing the way for continued success.

The following may be taken as an authentic record of the progressive output of the mines, with the local value of the ore, since the commencement of the industry in Canada in 1878. It would have been more satisfactory to have been able to show the relative increase in price per ton in each year, but that could not be done without a knowledge of the proportions of the annual output, ranking as Nos. 1, 2, and 3. So far as possible, I have endeavoured to show this for 1889, and doubtless the importance of the industry will lead to greater particularization in future official returns. The advisability of

this is practically recognised in Mr. Brumell's last Report (1889), which is a model of detailed accuracy :—

	Tons.	Value at the Mines.	
1879	300	$19,500	£4,020
1880	380	24,700	5,093
1881	540	35,100	7,237
1882	810	52,650	10,856
1883	955	68,750	14,175
1884	1,141	75,079	15,480
1885	2,440	142,441	29,369
1886	3,458	206,251	42,526
1887	4,619	226,976	45,562
1888	4,404	255,007	52,578
1889	5,919*	—	—

The official Report for 1888 states that the price of first-class asbestos was then firm at an increase over previous years, the quality of the mineral shipped being correspondingly higher. During 1889, especially towards the close of the year, the prices of asbestos lands were considerably augmented, and the prices of crude ore advanced by "leaps and bounds."

It is not possible to give tabulated statements of production and prices, because this is the first year in which production and value has been authentically given for the full year. For the year 1888 a new system of returns was inaugurated by the Government officers, and from that time forward authentic figures will be tabulated.

Returns for this year (1888) were sent in by all the producers (11 mines, of which 9 only were productive), showing an output for the year of 4,404½ tons of all grades, valued at the mines at $255,007 (£52,578), an increase of 185 tons in quantity and $34,031 (£7,016) in value over the figures of the previous year.

The output from Ontario (actinolite returned as asbestos) for the previous year was 400 tons, value $6,000 (£1,237);

* This figure is that given by the Commissioner of Crown Lands for the year ending 30th June, and is consequently not the correct figure for comparison with those up to 1888, which are for the year ending 31st December, the official returns not being yet published.

for 1888 it was nil. Consequently the production is shown as follows:—

From Thetford Mines	3,067 tons.
„ Coleraine and Black Lake . .	1,337½ „
	4,404½ tons.

These amounts were made up as follows:—

Thetford No. 1 . .	1786 tons, valued at	$157,040	= £32,379 7 7¼
„ No. 2 . .	519 „ „	29,740	6,131 19 2¼
„ No. 3 . .	762 „ „	11,430	2,356 14 0
	3,067 tons.	$198,210	£40,868 0 9½
Coleraine and Black Lake No. 1 .	337 tons, valued at	$25,040	= £5,162 17 8¼
„ No. 2 .	601 „ „	26,495	5,462 17 8¼
„ No. 3 .	399 „ „	5,262	1,084 18 11½
	1,337 tons.	$56,597	£11,710 14 4
Totals—No. 1 . .	2,123 tons, valued at	$182,080	= £37,542 5 4¼
No. 2 . .	1,120 „ „	56,235	11,594 16 10¾
No. 3 . .	1,161 „ „	16,692	3,441 12 11¾
	4,404 tons.	$255,007	£52,578 15 3

The quantity exported in the same year (1888) was as follows:—

No. 1 . . .	3,625 tons, valued at	$262,552	= £54,134 8 8
No. 2 . . .	110 „ „	5,306	1,094 0 5
No. 3 . . .	201 „ „	9,884	2,037 18 9
	3,936 tons.	$277,742	£57,266 7 10

Out of this total export no less than 3,612 tons, as already stated, was taken by the United States, the insignificant remainder being divided between Great Britain, France, Germany, Belgium, and Newfoundland.* The figures for 1889

* Brumell's Report on the Mining and Mineral Statistics of Canada for the year 1888.

and following years will show very different results, as the whole of the produce of three of the mines will now be sent to England direct, and of one other to Germany.

The Report of the Commissioner of Crown Lands for the Province of Quebec for 1889* gives important information as to the further working of the mines, but it is, unfortunately, useless for purposes of comparison, as, instead of dealing, like the former, with the whole year 1889, the Report makes the year end with the 30th of June, in the very height of the season, when facts and figures would be more difficult to arrive at accurately. For this reason, apparently, the figures are given as approximate only, and without any indication of classes or value. This question of date-discrepancy must be borne in mind, or the figures will be difficult to reconcile with known facts, especially in the general scale of prices, which are now much higher all round.

According to this last Report the output from the several mines for the twelve months ending 30th June, 1889, was as follows:—

THETFORD MINES.

Bell's Asbestos Company	1,800 tons.
King Brothers	700 ,,
Johnson Company	900 ,,
Ross and Ward	360 ,,
Thetford Asbestos Mining Company	80 ,,
Lucke and Mitchell (prospect)	10 ,,
	3,850 tons.

BLACK LAKE.

Anglo-Canadian Asbestos Company	618 tons.
United Asbestos Company (Frechette and Douville)	330 ,,
American Asbestos Company (Wertheim)	380 ,,
Bell's Asbestos Company	198 ,,
Scottish Canadian Asbestos Company	34 ,,
	1,560 tons.

* Rapport du Commissaire des Terres de la Couronne de la Province de Quebec pour les douze mois expirés le 30 Juin 1889.

COLERAINE.

Megantic Mining Company	100 tons.
Lambley & Co.	25 ,,
King Brothers (Ireland)	50 ,,
	175 tons.

DANVILLE AND BROUGHTON.

W. H. Jeffrey	328 tons.
Scottish Canadian Company	6 ,,
	334 tons.

TOTALS.

Thetford	3,850 tons.
Black Lake	1,560 ,,
Coleraine	175 ,,
Danville and Broughton	334 ,,
	5,919 tons.

In reference to which the Commissioner states that the Scottish Canadian Company and the Montreal Asbestos Company, of Black Lake, did no work during the year to which his report relates; and that the White's Asbestos Company, of Coleraine and Garthby, prospected only without any appreciable result.

"En resumé (the Commissioner concludes), l'industrie des mines d'amiantes est en pleine prosperité. Durant cette année, le prix a augmenté de 25 per cent., et la production 50 per cent. La demande continue d'être très grande, et les terrains miniers sont très recherchés."

The result of the twelve months' working ending 31st December, 1889, according to other (official) returns, are given as—

From Coleraine	124 tons.
,, Black Lake	1,725 ,,
,, Thetford	4,083 ,,
,, Broughton	8 ,,
,, Levis	16 ,,
	5,956 tons.

During 1889 the consumption of asbestos, in America especially, increased so rapidly that the demand was again greatly in excess of the supply. It is therefore manifest that, unless the production can be largely augmented, prices must still continue to rise. During the autumn, when the season was closing, none of the producers would venture to make contracts on any terms. Contracts for the previous season's delivery had in many cases to be deferred, and as a consequence of that it was found impossible to fix a price for the raw material even for a month in advance; nor was it practicable to obtain a guarantee for the delivery of the quantity which had been contracted for in the previous year.

The contracts entered into, at the close of 1888, were at prices unheard of before, and as the whole of the produce of 1889 was bespoken, although not contracted for, there appears but little prospect at present of a reaction. Owners confidently anticipated an advance of 40 or 50 per cent. upon the then current rates, refusing to bind themselves even at that; and subsequent experience has shown that their anticipations have been more than realized. It is quite clear, therefore, that no reduction in price is to be anticipated at present.

To give a general idea of the increased prices obtained it may be mentioned that, during the years 1881, 1882, and 1883, the prices of No. 1 crude were respectively $50, $60, and $70, rising by $10 each year; whilst in the autumn of 1889 they had risen to the following: No. 1, $125 to $130; No. 2, $75 to $80; No. 3, $35 to $40, and "waste," which had hitherto been unsaleable, $15 per ton, the ton being the short Canadian ton of 2,000 lbs. only; and the prices named being those obtainable at the mines. In the early part of 1890, $150 per ton was given for No. 1, and in the second week of April a parcel of 20 tons was bought in London at the rate of £43, or $208 per ton.

In June, 1890, the latest price received from New York was £53, with every prospect of its going still higher.

It must not, however, be forgotten that in the quoted prices there is a considerable variation, which is due to the fact that

no uniform system of grading is adopted at the various mines. Thus, while at one mine No. 2 will be quoted at $75 per ton, at another the price of No. 1 will be very little more. Extra quality of No. 1, again, naturally commands a higher figure than the ordinary run of that grade.

It follows, therefore, that, when estimating the value of an asbestos property, the question of the relative percentage of output should be carefully considered; since, while the number of tons produced by any two mines might be approximately equal, and to the uninitiated, therefore, the properties about equal in value, the one, from the large amount of No. 1 grade, would be capable of paying handsome dividends, while the other would require great economy of management and still yield far less satisfactory returns.* Again, if a mine be worked on the hillside it is obvious that it will be comparatively free from water, and the removal of the ore and waste rock a simple process, whilst if it be on the level ground, and the mine be worked by sinking, the water trouble becomes greater every day, and powerful pumping machinery and steam apparatus for raising ore and waste rock must add greatly to the working cost, and consequently to cost per ton of ore got out.

Wages run from $1 to $1.75 a day, according to the nature of the work performed, for men, and from 50 to 75 cents for lads and cobbers.

These rates do not much differ from those paid in the adjoining province of Ontario. There, surface men employed at the Bruce copper mines were paid about $1 a day, though of course some could get more. At Sault Ste. Marie ordinary labourers at the mines get from $1.25 to $1.50 a day. On this important question of wages we see by the Report of the Royal Commission just published,† that in the Sudbury district, outside men can get $1.40, and miners $1.75, but it is somewhat difficult to get labour at Sudbury on account of the

* Dr. Ells, Second Report for 1889.

† Report of the Royal Commission on the Mineral Resources of Ontario and the Measures for their Development, 1890: p. 406.

isolated position of the mines. The following is the rate paid there in cash:—

Drill runners . .	$2.10 per day	Machinist . . .	$2.25 per day
Miners	1.75 ,,	Pumpman . . .	2.00 ,,
Labourers . . .	1.60 ,,	Fitter	2.00 ,,
Foreman	2.00 ,,	Fireman	1.50 ,,
Watchman . . .	1.75 ,,	Blacksmith . . .	2.50 ,,
Engineer	2.00 ,,	Asstnt. Blacksmith	1.75 ,,

As to the mode of extraction of the ore, the method of work in all the chrysotile mines of Canada is simply open quarry work, except at Broughton, where the peculiar formation necessitates a mode more in the nature of regular mining; and at Mr. Wertheim's mine, at Coleraine, where a new departure has been taken, by driving a somewhat extensive tunnel from the foot of the hill, and then a shaft through the rock to reach the pits above; though, in this last case, the operation is simply performed to open out a fine working face.

All the old rule-of-thumb methods of opening and working are now being rapidly discontinued, these being found to be quite impracticable with large pits and constantly increasing production. Air compressors, steam derricks, and all the most improved labour-saving appliances are being everywhere introduced, and a rich reward awaits the inventor who shall enable the mine-owners to dispense with the tedious and costly process of cobbing, more especially of the lower grades, and at the same time help him to get rid of some of the enormous masses of piled-up waste rock, much of which contains short veins of fibre, which under the present system will not pay for extracting, but every particle of which will be turned to good account when some economical process is devised for extracting it.

Whether the drills are worked by compressed air, or by hand, in the old-fashioned way, the effect is the same. When a sufficient number of holes of the proper depth are drilled and duly charged with dynamite or powder, they are linked together, and fired by a battery in such a way that the face of rock shall be thrown outward, on to the floor of the pit. The asbestos is then picked out, the adhering rock roughly broken

off, and the ore piled into boxes or tubs, which are loaded on to trolleys, and run off on tram-lines to the cobbing-sheds. The refuse rock, of which there is always an enormous quantity, (as much as twenty or twenty-five tons of rock to one of asbestos), is loaded into cars, run off and shot over on to the dumping-ground.

Boys are employed in the cobbing-sheds to chip, or cob, the rock cleanly from the ore, an operation which is much more troublesome with thin veins than with those of the better sort, to which the waste rock is less firmly adherent.

This cobbing is a very troublesome and expensive process, costing about $5 a ton. After cobbing, great care is required in sorting the ore into the respective grades of Nos. 1, 2, and 3. It is then put up in bags of 100 or 160 lbs. each, marked, and stacked away in the bins ready for shipment. All this is done in a very rough-and-ready style, and the waste is simply enormous; there is no doubt, however, that as the ore increases in value more scientific appliances will be adopted, and greater care used in the prevention of waste. At present thousands of tons of rock containing only thin veins of asbestos are dumped on the refuse heaps as waste which would all be crushed if a proper machine were at hand, and the valuable material consequently saved.

The sorting, or grading, of the ore is done by the cobbers simultaneously with the cobbing; the lads, whilst striking off the adhering rock, dividing the lumps of ore into Nos. 1, 2, or 3 class, and throwing them into their separate heaps, being guided in so doing by the colour and purity of the fibre, with a due regard to length. An investigation into the method and cost of this work, carried out by Mr. Obalski, showed that fourteen young lads in one day separated 4,000 lbs., or two Canadian tons, into graded and marketable material, their wages, at 70 cents each, reaching $9·08, or nearly $5 per ton; and he considered this below the general average cost of the work, which is probably nearer $6, bringing up the cost of production and preparation for market to about $25 per ton. This coincides pretty accurately with my personal experi-

ence. Taking, therefore, the prices at the mines at $125 only for No. 1, $75 for No. 2, and $35 for No. 3, and comparing these with the cost of production, it is evident there is a very large amount of profit in asbestos mining, and a considerable inducement for the employment of capital therein. And when it is stated that these calculations were made upon the old system of work by hand-labour, machinery being now the rule, whereby the cost of production is reduced to $15, and at old prices, it will be seen that the profit is very much larger than is shown above.

There is no scarcity of labour, a sufficient number of hands, mostly French-Canadians, being always forthcoming; but at those mines where there is an insufficiency of houses for married men, accommodation has to be found in a barrack-like building for single men: the married men, who cannot be accommodated, residing frequently at a long distance from their work, which causes them to be of a migratory disposition, and gives considerable additional trouble to the management. This remark, however, does not apply to Thetford, to Wertheim's, or, indeed, to any mine started on a business-like basis, as in such cases proper regard is paid to the welfare of the men by providing them with suitable accommodation.

A disadvantage in the employment of French-Canadian labour lies in the great number of festivals incident to their religion, with consequent loss of work at the mines, but apparently there is no remedy for this at present. The greatest curse of the place, however, is drink. The hip pockets in the men's pants form very convenient receptacles for bottles, and these are always pretty well filled after pay days and holidays. The liquor most in favour is a vile compound called gin. It is supplied in the regular square Dutch bottles from the familiar green-painted boxes in which "Hollands" is exported, and which are labelled "De Kuyper"; but the vile stuff is not much credit to that gentleman's manufacture if it be so, which is much to be doubted.

Although the district is under the Scott Act, and the sale of liquor consequently prohibited, like every other place where

the sale is interdicted there is no difficulty, if you know how to go about it, and sometimes even if you don't,* in getting as much liquor as you please. At any rate I never yet was in any such place where I did not find it to be so, the only practical difference being that, in the absence of competition, the spirits obtainable are the vilest compounds imaginable.

According to my experience, no sooner is the sale of spirits interdicted anywhere than a craving for drink sets in like an epidemic, coupled with a determination to get it, and that unmitigated curse to any community, secret drinking, becomes rife. Practical experience soon taught me the comparative uselessness of alcohol when travelling in cold regions; the Russian fashion of tea-drinking is far and away the best. A tumbler of hot tea, flavoured with a slice of lemon, is not only palatable and comforting, but will carry a man twice as far as any concoction of alcohol.

In concluding this part of the subject, it may be well to point out that prior to the purchase of an unexplored asbestos property, it would be well to learn something of the surface indications, as well as the geological formation and surroundings of the property; and if the ground be opened, the

* Here is an instance: On one occasion I had been out driving in the pouring rain for several hours, had got drenched to the skin, and was bitterly cold. I pulled up, therefore, at a likely-looking house, went in and called for some brandy, but to my disgust was told that no liquors could be supplied, as it was against the law. As I turned to go out again, in no very cheerful mood, the man, seeing the state I was in, evidently took compassion on me, and said, "Better try some bitters"; so calling to mind the saying that all bitters are warm, barring a bitter cold day, which only proves the rule, I assented. He then pushed over a tumbler and a black bottle, when I at once poured out and swallowed a pretty strong dose, feeling when I had done so as if I had swallowed a streak of forked lightning. As soon as I had recovered my breath I muttered my thanks and paid up. "Have another?" says he, with a twinkle in his eye. "No, thanks," I replied. "Guess you'll remember our bitters," he then laughingly said, prefixing the name of the place, which I afterwards found was in a district where prohibition was very strictly enforced, and which I therefore purposely omit, his breach of the law having no doubt saved me from the dangerous effects of a chill.

direction and dip of the veins, the presence or absence of chromic iron ore, pyrites, or other minerals in association with the asbestos ore, the quantity and quality of the ore producible from the adjoining mines, and its analysis. Special regard must also be had to its tenacity, lubricity, flexibility, and infusibility. The most suitable method of extraction, the best arrangements for dumping, with the important questions of transport, cost and supply of labour, &c., and last, but not least (if the mine be at work), the relative proportions of grades producible, are important matters for consideration.

Upon this last point deception may easily be practised on the unwary ; figures of prospective output and corresponding profit are sometimes put forward, which, if accepted without proper advice, are certain to lead to trouble, and perhaps to disaster. In one case of a mine put on the English market, it was boldly stated that the output for the first year might be taken at about 67 per cent. of No. 1, whereas the first year's production showed 67 per cent. and upwards of No. 3, which did not pay for working, some small amount of No. 2, and an almost infinitesimal amount of No. 1. In another case there had been no reliable expert's opinion obtained as to the quality of the land before purchase, and when work was commenced the ground bought proved to be barren. In both cases the money had better have been thrown into the Thames, as well in the interest of the shareholders as for the credit of Canadian enterprise.

When failures occur, they may almost certainly be traced to want of practical advice in the first instance, to incompetency or extravagance in the management, or to overcapitalisation ; but with due care, economy, and honest and capable management, there are but few things which will pay better or with more regularity and certainty than mining for asbestos.

CHAPTER VII.

NEWFOUNDLAND AND NORWAY.

General Resemblance of Strata to Gaspé—Granite, Serpentine, Asbestos, and Picrolite — Pseudo-Chrysotile — Crocidolite — Coarse Asbestos—Minerals found in Norway.

So great a resemblance exists between some parts of the geological formation of Newfoundland and that of the Gaspé Peninsula, with parts of the Eastern Townships of Quebec, of which the former is doubtless a continuation, that it is naturally to be expected the same minerals would be found there, including asbestos. The Quebec group, a continuation of the Appalachian chain, is part of the great metalliferous formation of North America. In this group, as we have already seen, are found gold, silver, copper, asbestos, magnetic and chromic iron, cobalt, nickel, and some other minerals. These are associated with the ophiolites and other magnesian rocks, whilst they are apparently wanting in those of the same age in the Laurentian series. This fact was recognised by Dr. Sterry Hunt in 1881.* And Mr. Alexander Murray, then geologist of Newfoundland, when treating of the Lower Cambrian Rocks of Nova Scotia, compares them with the auriferous strata of his Intermediate series of Newfoundland. The resemblance in general character of the strata, with their included auriferous quartz veins, in Newfoundland to those of Nova Scotia, will occur to any one who has visited the two countries, and studied

* *American Journal of Science*, May, 1881.

their geological features, and I venture to say that the description given of the latter country might, in many respects, equally apply to the former; although the auriferous country of Nova Scotia is supposed to be of Lower Silurian age; whilst that of Newfoundland is undoubtedly unconformably below the Primordial.*

Gold has been found in many parts of this series, and asbestos also in the serpentine rocks of Newfoundland. The distribution of these latter is a matter of great importance to those interested in the discovery of metalliferous ores as well as of asbestos; the formation of which they are a part is largely developed in various parts of the island, and there is good reason to believe that, in course of time, the latter will become a great field of mining industry.

One day a friend of mine, while out shooting on the island, had to cross a mountain stream near the shore, and in passing over, saw a long-fibred white substance swaying about in the water, which he took for some kind of vegetation, but on pulling it out it proved to be asbestos. And on the banks of the stream he found it filling all the crevices in the rocks, which there and for some miles along the coast are all magnesian. Some specimens of the asbestos he gathered, and brought home with him to England. They were long, and of a fine white colour, in appearance exactly resembling that found in the Pyrenees, but brittle, and consequently of little value. From the description of the place where it was found there would appear to be little doubt that a seam of asbestos exists in the locality which would pay for working.

There are large developments of serpentine on other parts of the island, asbestos also being found in many places, notably on the north side of Hare Bay and between that place and Pistolet Bay. Some considerable extent of asbestos-bearing serpentine also occurs on the west side of the island; likewise at York Harbour, in the Bay of Islands, and running from the north arm of that bay to Bonne Bay.

* "Geological Survey of Newfoundland, 1880."

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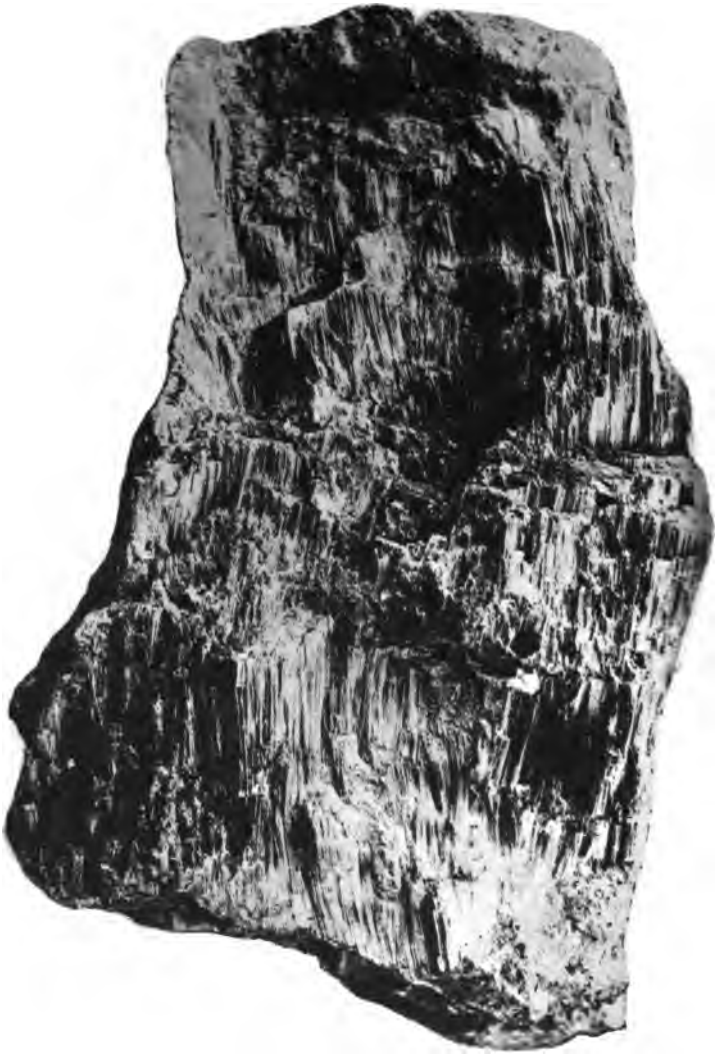


MOUNTAIN WOOD, HELGELAND, NORWAY.

At Tilt Cove great masses of serpentine and steatite occur, the magnesian rocks in that district being permeated throughout by magnetic and chromic iron in grains and crystals. In front of this, and overlying the mineralized lands, are masses of a hard, grey diorite, containing epidote in strings and patches. This is succeeded on the north-west by the great body of serpentine of the Castle Rock depression. A very soft and shaly serpentine containing asbestos is found here, the veins averaging at the surface a quarter of an inch in width.

On the west side of Tickle Harbour, north of Long Reach, is a group of altered rocks consisting of purple and variegated slates associated with serpentine and steatite, the veins of asbestos being intersected with layers of yellowish quartzite.

There is also a large development of picrolite towards the top of Sitdown Hill, which runs through the rocks and breaks out in long fibrous crystals, the surfaces of which are sometimes opalescent. Seams of asbestos are also frequent here; indeed it is manifest that there is abundance on the island, which is ripe for exploration.

Norway.

Norway is one of the oldest regions of Europe. A great part of it bears evidence of having been raised above the ocean level at a very remote period. Comparatively speaking, no other country exhibits such extensive areas of those primary or palæozoic rocks which form so large a part of the oldest crust of the earth.

The physical features of the whole of the Scandinavian peninsula are of a striking character. A chain of mountains runs from north to south nearly its entire length, which in a considerable part of its course forms the divide between Sweden and Norway. Nine-tenths of this latter country are of a bold, mountainous character, the valleys being mere rents or chasms, sometimes not more than a hundred feet wide, at the bottom of which runs a fjord, or a river winds its

tortuous course as it rushes down to the sea, the enclosing mountains rising up in grim and bare sterility to an occasional height of about 4,000 feet. So strange, indeed, is the conformation of the country that Victor Hugo could only liken it to the skeleton of a great fish. Such a country as this is specially favourable for deposits of the economic minerals.

Granite, which is not generally favourable to asbestos, occurs everywhere; serpentine, nevertheless, abounds there as well as throughout the whole of Scandinavia. It occurs in massive form at Fahlun in Sweden, and crystallized massive at Snarum and many other parts of Norway, especially in the south. Precious serpentine occurs at Fahlun and Gulsjo, as well as a soft earthy variety, somewhat like meerschaum, with considerable quantities of picrolite.

Amphibole is an essential constituent of such rocks as syenite, diorite, and greenstone, and asbestos is frequently found associated with the greenish apatite rocks of South Norway, at Arendal, Snarum, and other places, where rutile, actinolite, chlorite, and epidote also occur. It is also found at Sundmoër, and a pseudo-chrysotile also occurs which has the following composition:—

Silica	42·92
Alumina	·87
Ferric oxide	2·28
Magnesia	41·66
Water	12·02
	99·75

There can be no doubt of the valuable character of this mineral; but, as a rule, most of the asbestos hitherto brought from Norway is coarse and hard, resembling mountain wood, mountain cork, and leather; in the limestone especially it partakes of the latter character. The whole of Norway has the appearance of a mighty upheaval of the primitive rocks, granite, gneiss, and syenite especially, varied, particularly on the coast line and along the fjords, by patches, in some cases miles in length, of serpentine and hornblende.

A variety of crocidolite is found at Stavern, which bears some resemblance to the African species.

At Helgeland, on one of the fjords, further to the north-west, beyond Trondheim, the serpentine, varied by masses of hornblende, runs for something like three miles in a heaped-up mammillated form, until suddenly cut off by a great upheaval of granite. Here, as might be expected, there is abundance of asbestos. That lying near the surface is of the usual Norske character—coarse and woody. Eight or ten small openings have been made between the boulders of serpentine and a few tons got out, which was sent to London and converted into cement, paint, and used up for other purposes to which pulverised asbestos is adapted. This was got out, shipped and delivered in London at something less than £6 per ton, at which price any quantity could be sold; the cost of extraction, transport, and delivery being about £3 10s.

A better quality, but still also partaking of the nature of mountain cork, occurs here and in the limestone region on the opposite side of the fjord. Still, with the fact before us of asbestos of fine quality occurring in this neighbourhood, we are fully warranted in expecting that when the time comes for exploration, the coarse, woody variety, supposed to be characteristic of the country, will be found to be merely the surface deposits, and that richer stores are to be had for searching, whilst even these inferior ones would well pay for working.

In the Report of the Royal Commission on the Mineral Resources of Ontario (1890) it is mentioned that Mr. Willimott has enumerated 61 species of minerals as distributed in the Upper Laurentian rocks of that Province; and these, almost without exception, are to be found in rocks of a similar character in Norway. Among these granite is everywhere conspicuous, in association with syenite, which abounds in zircon: pegmatite or graphic granite occurring in veins. In the north gabbro, greenstone, and granite are found among the eruptive rocks, whilst in central Norway the formation is mostly overlaid with clay slates and quartz.

CHAPTER VIII.

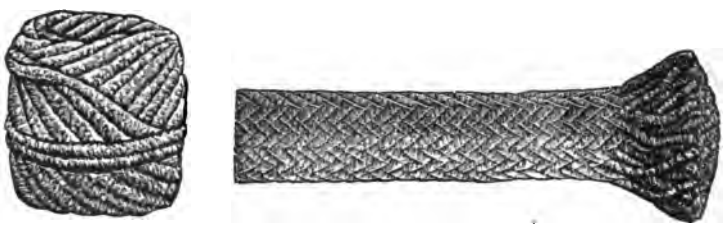
THE USES OF ASBESTOS: APPLICATION TO ENGINEERING PURPOSES.

EARLY EXPERIMENTS—Causes of Failure—Packings—Boiler Coverings—Fire-felt—Fire-felt with Superator Covering—Cement—Asbesto-Sponge—Joints of Hot-air Pipes.

ALTHOUGH many of the valuable properties of asbestos have been known, as we have already seen, for thousands of years, we are only now concerned with it in its modern adaptation to the industrial arts and practical mechanics. Its use, in this respect, dates from but a few years ago; nor can the first attempts to render it available be even then looked upon otherwise than as experiments, which were mostly of an unsuccessful character. One of the main causes of this failure was that the varied and dissimilar peculiarities of the different varieties were not, at that time, properly appreciated; nor was the requisite attention given to differences of composition. Even now, the economic value of the greater number of species is so far unknown that no use can be made of them; but as we know that there is nothing, in or under the earth, which cannot be made available for man's use, we may confidently expect that the rich deposits known to exist in various parts of the world, in America, in Africa and Servia especially, will presently be utilized. At this moment scarcely any but the fine silky and tenacious fibres of Italy and Canada find practical application; and as the value of these, for an infinite variety of purposes, day by day becomes more perceptible, the demand for them as rapidly increases, to a degree, so far as Canada is concerned,

certainly far beyond the rate of supply. We can, therefore, only anticipate that these special varieties will become more and more valuable, until either fresh mines are discovered or means are found for bringing some of the, at present, unused varieties into competition with them for some at least of the commoner purposes to which they are applied.

The earliest modern application of the fibre to engineering purposes was the manufacture of an improved packing. This, at first, was mostly in the shape of millboard, but the various modifications of this special manufacture now in demand are so many that it would be useless to attempt to enumerate them here. It may be, however, that a general mention of some few of those



Asbestos Wick and Braided Packings. Chalmers-Spence Company, New York.

now in use in steam, hydraulic and electrical machinery may not be considered out of place. The utility of asbestos for such purposes as these, like that of every other material so used, depends a great deal upon its freedom from impurity. When the manufacture was first commenced, it was frequently found that the fibres were more or less charged with minute particles of pyrites, of magnetite, or other metallic impurity, which caused the piston-rods to be scored by the packing, and the damage thus occasioned was at first erroneously attributed to the action of the asbestos itself rather than to the impurities contained in it. As soon, however, as the real cause of this was properly appreciated, it became necessary, in order to prevent it, not only to select the most suitable kind of asbestos

for this special purpose, but also to thoroughly cleanse it from all gritty matter before spinning; and in order effectually to accomplish this object, special machinery had to be devised, but as soon as this was done the yarn produced was pure and capable of being woven into any kind of fabric.

Whatever the material may be which is used for this purpose, it is a matter of the first necessity that, under the action of steam or heat, it shall not become hard in the gland; and its nature must be such that it shall remain unaltered, however high the pressure, or fast the steam, to which it may be subjected. The native qualities of asbestos admirably adapt it for such purposes as these, its inherent lubricity rendering it additionally valuable; and by its use a perfectly pure packing can now be produced, through which the rod slides with a minimum of friction. Another great point is that it does not require frequent renewing; regularity in the motion of the piston is preserved and all the machinery connected with it runs with perfect smoothness, its elastic nature keeping the joints tight, longer than any other kind manufactured.

Sometimes, it is true, more is claimed for these packings than they can accomplish, it being occasionally asserted that their self-lubricating qualities enable them to be used without oil. This is not so; they require a plentiful supply of oil and very careful attention as well: but these being given, they will last from five to ten times longer than any packing now in use. They possess many advantages over rubber, their weight is less, they last longer, and one half the thickness will generally suffice.

The various packings, in all the ordinary forms, made by the United Asbestos Company, of London, are too well known to need description here, and their Victor metallic packings are used wherever such goods are required.

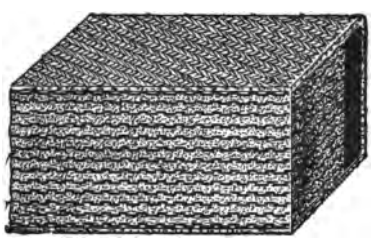
As a special method of utilizing asbestos for packing, "Eastman's Asbestallicon" may be mentioned; and the combined asbestos and metallic packing of Messrs. Witty & Wyatt is also well spoken of. In this, soft metallic rings, of two forms are made, in two or three segments, with an asbestos ring attached

to the segments, this last being only severed in one place. The segments are thus held together, and are put in place so as to break joint; the metal and asbestos press together, and are sufficiently free to follow any irregularity in the form of the piston-rod, and still remain quite steam-tight.

Dick's self-lubricating steam and hydraulic packing is made of native jute, which nearly approaches the texture of silk; each yarn, in the process of manufacture, being passed through

Round Rope.

Round Core.



The "Duriflex."

an asbestos compound, whereby a good all-round packing is formed.

Cresswell's "Special Marine Asbestos Packing" is manufactured for use in ocean-going steamers, fitted with triple-expansion engines, running at great and continuous speed.

The "Duriflex," of Messrs. Moseley & Sons, Manchester, is constructed of wire gauze and asbestos, so contrived as to combine the durability of a metallic with the flexibility of a

fibrous packing, and this either with or without an indiarubber core, as shown on the previous page. The wire gauze is prepared, before insertion, by cutting or corrugating it diagonally, and then placing it between the layers of fibrous material with the corrugations diagonally arranged. By this means the rigidity of the wire gauze is entirely destroyed, and the packing has practically as great flexibility as one made entirely of fibrous material.

The "Manhattan," of the Manhattan Packing Company, New York, is a plumbago packing designed to prevent grooving and cutting. It is formed of a braided strip, either with or without a rubber centre, filled with fine floated plumbago, and with an oil of very high fire test, which cannot char or ignite, and is free from acids. It is specially useful in steam hammers, where it is desirable to avoid a leakage of steam or water, or on rotary bleach boilers.

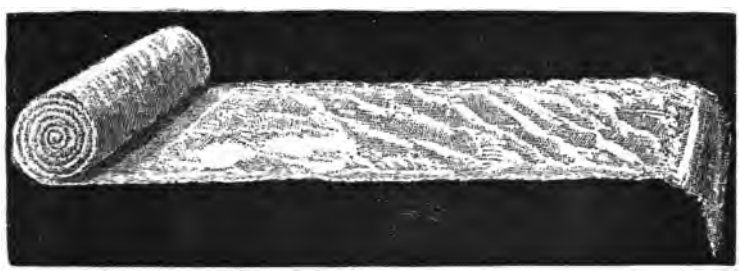
The "Manhattan."

As a packing for steam cocks, the use of asbestos is well-nigh universal for high-pressure fittings, the great heat of the steam speedily destroying any packing made from hemp; but as the joint in this case is made between a metal surface and one of asbestos, sufficient room is required to be left between the plug and the shell to allow for expansion. Dewrance's asbestos-packed cocks are too well known to engineers to need more than reference.

A durable joint can be made between rough cast-iron surfaces by the use of asbestos mixed with sufficient white lead to make a stiff putty.

The various coverings designed for the protection of boilers and pipes, for the preservation of the contained heat, and for the economy of fuel are specially numerous. Asbestos practically contains in itself every requisite for a perfect non-

conducting covering, and consequently the most satisfactory results are obtained by using it in this way, in its pure and fibrous form, without any admixture of foreign material. One of the largest and most enterprising firms of asbestos manufacturers in the United States, the Chalmers-Spence Company of New York, has given to this department of manufacture considerable attention, and has designed a material for the purpose which they term Fire-Felt. In their construction of this covering, the mineral fibres are formed into cylinders, blocks, and sheets, according to the shape and size of the surfaces to be covered; and these being light in weight (1 lb. to the square foot, 1 inch thick), flexible, and easily handled, can



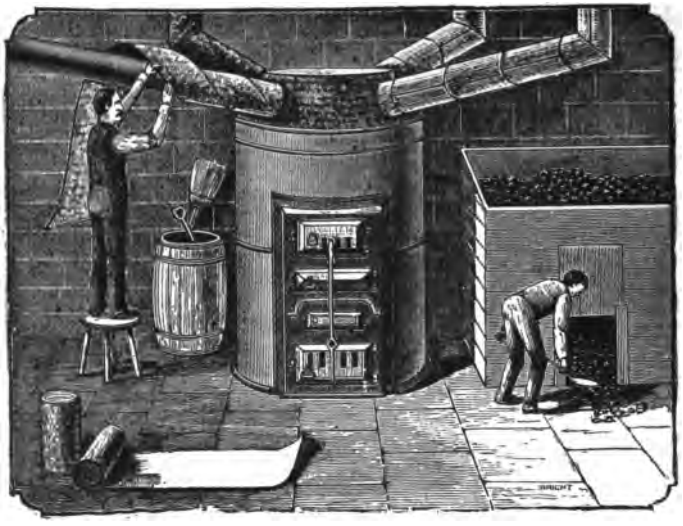
Fire-Felt. The Chalmers-Spence Company.

be readily adapted to a surface of any shape; whilst, being strong and tough on the exterior, and spongy and felt-like on the inner layer, they form a highly non-conducting material.

When tested with any of the various composition coverings produced, the superiority of the pure and fibrous asbestos, in this form, is quickly seen. It gives better non-conducting results, and possesses a guarantee of durability impossible to be otherwise obtained, inasmuch as it cannot char or burn out, because there are no organic or perishable materials included in its make-up.

Another form of this material is shown in the same firm's "Patent Roll Fire-Felt," which is made in rolls of about 3 feet in width, and of any required thickness. This is specially

useful as a non-conducting fireproof lining under other coverings, or as a covering by itself, where great thickness is not desired, as in most kinds of steam-pipe work. In length each roll contains about 300 square feet. High pressure being now the rule, seldom less than 80 or 90 lbs. which means a body of heat of 300° Fahr., or over, contained in one quarter-inch thickness of iron, and rapidly conducting through the iron, it is of primary importance to prevent this heat from escaping,



Patent Roll Fire-Felt. The Chalmers-Spence Company.

not only when the covering is first applied, but also during a term of years, and this requires a material of high non-conducting powers and great durability.

Fire-felt possesses these qualities in an eminent degree, as it is free from any ingredients that will cause it to disintegrate under heat or deteriorate through use. Its mode of application to house furnace pipes is shown in the diagram above.

A special boiler covering, manufactured by the same firm,

and supplied by them under contract for several of the United States Government warships, is in the form of a quilting. These quiltings weigh about 2 lbs. per square foot, and can be removed without difficulty when required. The same firm also manufacture removable pipe coverings; some of these are made exclusively of pure asbestos fibre, and others of asbestos

Patent Removable Covering.

combined with other materials, according to whether high or low pressure steam is used, or whether it be for the preservation of cold-water pipes from freezing.

These coverings are made in sections of three-foot lengths, of the exact size of the pipe to be covered, the asbestos fibres in the covering being so interlaced that the sections, whilst

Fire-Felt with Canvas Flap.

combining strength with flexibility, afford so large a number of air-cells as to give this covering a very high non-conducting quality, whilst it is not liable to char or be otherwise injured by the most intense heat. It is occasionally found advisable to provide a heavy inner layer of asbestos fibre, with an outer layer of hair felt; but if a layer of asbestos fibre be substituted

for the hair felt, greater durability is ensured. In whichever way the fibre is used, it is enclosed in a strong case or wrapper of non-porous sheathing, the inner section of which has a lining of asbestos to keep it from direct contact with the iron.

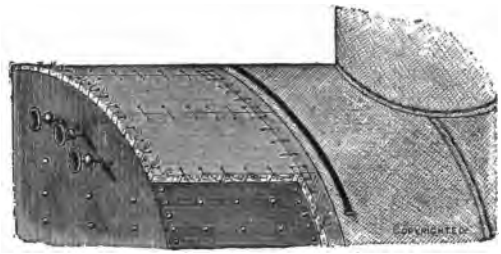
This patent Fire-felt is also furnished with a canvas flap cover, and when the pipes are to be used in wet places, out of doors, or in mines, a special class of "Superator" jacket is provided, thus:

Fire-Felt with Superator Jacket.

The material which the patentee calls "Superator" is another speciality of the same house. This is a flexible sheet of asbestos, strengthened by an insertion of wire-netting. It is made of mineral substances only (mainly asbestos), with an admixture of some insoluble chemical ingredients, the asbestos rendering the jacket fireproof, and the wire netting giving it the necessary strength.

The material of which the Superator is made is waterproofed by a patent process, and will consequently resist any degree of moisture, thus forming a substantial protection to the covering. Superator is also used for roofing purposes, sheathing wooden structures exposed to the weather or to sparks, &c.

Asbestos cement is also very largely used for covering boilers, steam-pipes, hot-blast furnaces, and stills. This is made of pulverized asbestos, for which the inferior qualities will answer sufficiently well, it is worked up to about the consistency of mortar, and spread over the surfaces to be covered in precisely the same manner, with a trowel. In place of this cement, the Chalmers-Spence Company propose a substitution of sheet Fire-felt with Superator jacket, thus:



Sheet Fire-Felt with Superator Jacket.

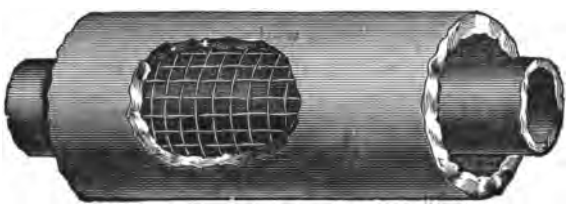
Where the cement is preferred, in the preparation of it certain chemical ingredients have to be added which, while not injurious to the metal, cause the asbestos to adhere firmly to the plates, so that when dry it becomes quite hard and can be walked over without being injured. With a boiler carrying say 80 lbs. steam pressure, the application of from 1½ to 2 inches of this composition so well retains the heat in the boiler that a thermometer with the bulb held close to the outer surface of the covering will not indicate more than 80° to 85° Fahr., and when the boilers, steam-pipes, &c., are covered in this manner, a large saving of fuel is effected, as it is said, equivalent to 33 per cent. The non-conducting power of asbestos is twice as great as that of hair felt, which is believed to come next to it in value, but is soon destroyed by heat. When the steam pressure is not unusually high, one inch in thickness of the cement is sufficient; but the additional cost of an extra half-inch is amply compensated for by the larger proportionate saving of fuel and power effected by its use.

The cement, which is made from a cheap quality of asbestos, is now in common use in Canada and the States, where, as already shown, it is found to operate with a twofold effect, viz., by lowering the temperature of the boiler-house, to the great comfort of the engineers and firemen, and also, in a very marked degree, economising the expenditure for fuel. Unprotected pipes require a greater supply of fuel, and mean more wear and tear on grate bars, boilers, &c.; while in order to

convey steam any distance through unprotected pipes requires a much larger pipe to furnish the requisite power.

It seems strange that the use of asbestos in this country, in this way, has as yet made so little headway. In one of the palatial buildings recently erected in London, where engines are required to be in constant work for pumping water for working the lifts and for general purposes, as well as for the dynamos, the heat from the boilers forms so great a nuisance, and occasions so much loss in other ways, that very considerable expense was lately about to be incurred with a view to lowering the temperature. When conversing with an expert, who had been sent for to devise a remedy for this, I asked whether the use of asbestos would not effect the desired object. Certainly it would, he replied, but it is too expensive.

In applying the cement the best results are obtained when it is put on with an air space left, as shown thus :



Cement, with Air-space left.

This is another patent of the Chalmers-Spence Company. A network of lathing or wire-cloth is formed round the boiler or pipes, at a distance therefrom of about an inch. On this framework the cement is applied, the material keying through the meshes of the wire, and thus obtaining a greater hold and consequently greater durability than if it were applied direct to the iron.

An asbestos cement felting is also manufactured in New York, for use in the same way as the ordinary asbestos cement. This is composed of fibrous asbestos, and a cementing compound forming a light porous covering, which is applied in much the same way.

Another material is a substance called asbesto-sponge. Recognising that in all non-conductors the manufacturer's endeavour is to provide as large a number of air cells in a given space as possible, the patentee considers that sponge, which is composed of fine, flexible, tenacious fibres, interwoven in the form of cells and meshes, constitutes the ideal structure of a perfect non-conductor. The tintack-like barbs of the sponge are so interwoven, in asbesto-sponge, with the fine, silky fibres of asbestos as to form an elastic, highly porous material, of so light a character that a barrelful in the form of filling will barely weigh 50 lbs., and this with so small a percentage of sponge that the material is practically fireproof.

In making the joints of hot-air pipes for blast furnaces, which are necessarily exposed to an exceedingly high temperature, asbestos in the form of a cord has been found very serviceable; the jointing piece consisting of an iron ring, wrapped round with cord, which is simply put in place and nipped between the two flanges. Previously to the manufacture of asbestos cord these rings were wrapped round with yarn, which gave incessant trouble.

A new material of a composite nature which the patentee calls "Randalite," is prepared and sold by Messrs. S. Minns & Co., of Trafalgar Road, Dalston, as an improved Millboard for washers, packing, &c. This is waterproof, incorrodible, and unaffected by heat, cold, or grease. It is sold in sheets at 8d. per lb.

It is by no means to be said that all the varied applications of asbestos to engineering purposes have here been noted, but merely a selection of some of the most prominent. Indeed, it would be difficult to say for what special engineering purpose asbestos cannot be made available; an enlargement on this head would probably be considered of too technical a character to be of general interest, and enough has doubtless been said to show the great importance of the mineral in an engineering point of view.

CHAPTER IX.

APPLICATIONS OF ASBESTOS TO MILITARY AND FIRE PREVENTIVE PURPOSES.

Big Guns—Miners' Safety Lamps—Torpedoes—Time Fuses—Dynamite Shells—Ironclads—Military Aeronautics—Safes and Deed Boxes—Carriage of Explosives—Lint—Building Operations—Bâches—Theatrical Curtains—Protection Shields—Fires in Theatres—Captain Shaw's Book—A Yankee Yarn—Fire Kings—Firemen's Clothing—Appareil Aldini—Barnum's Show.

THE bearings of asbestos on matters connected with the art of scientific warfare are numerous and important. We have the authority of Sir Frederick Abel for stating that asbestos is as effectual when used for closing the breeches of big guns so as to prevent the passage of gas, as it is for ensuring safety (in a more peaceful application) in the same way for miners' lamps. In these last it was for a long time found very difficult to get a good joint between the metallic and the glass parts of the safety-lamp, and a great many different materials were tried for filling these joints in such a way that air should not be able to pass through. In many cases the air was contaminated with a certain amount of gaseous material which would be likely to render the whole explosive, and if this got through the joint between the glass and the metal, there would be very serious risk of explosion. A great number of substances were tried but found unsatisfactory, and after some hundreds of experiments had been made by Sir Frederick Abel and Sir Warington Smyth, with asbestos washers, these were ultimately found to maintain their condition most admirably.

With regard to closing the breeches of big guns, we are

informed, also on the authority of Sir Frederick Abel, that the only contrivance which could be called an approach to a perfect arrangement, was one devised by a French artillery officer, M. Dubange, which consisted of a kind of pad of asbestos fibre attached to the breech-loading arrangement. This, from its mineral nature, was nearly indestructible, and consequently lasted without material deterioration for a great length of time, notwithstanding that it was subjected to the enormous pressures which are now developed in the bores of very heavy guns.

In connection with Whitehead torpedoes, we learn, from the same authority, that in these and other similar receptacles, within which charges of wet gun-cotton are enclosed, the use of asbestos is found to overcome a great difficulty. The vessels containing the damp cotton have to be soldered, in order to keep them perfectly air-tight, and thus prevent the water from escaping; and in order to do this with anything approaching safety the space between the gun-cotton and the metal surfaces which have to be soldered were formerly filled with damp felt wads or discs. This seemed to answer the purpose, but it was found after they had been stored for some time that the effect of the moisture on the felt was to cause it to undergo a kind of decay or fermentation, resulting in the formation of gas to such an extent that the vessels were distended, and threatened to burst, and sometimes actually did burst with considerable violence. Asbestos millboard was substituted for the felt, and the difficulty and danger were then removed; gas was no longer evolved, whilst the operation of soldering could be performed with safety, the material remaining perfectly unaltered.

In the manufacture of time-fuzes, again, asbestos washers are found most valuable. Washers of indiarubber and wash-leather were formerly used, but these in time became hard, and acted on the metal surfaces with which they came in contact in such a manner as to cement them together, instead of keeping them mobile, and it was not until the introduction of asbestos washers that difficulties, in connection with the proper

action of these ingenious contrivances for the explosion of shells in a given time after their discharge, were removed.*

Experiments recently made with dynamite shells have revealed certain defects in their construction which have been overcome by the use of asbestos, and this terrible engine of warfare has been thereby in a great measure perfected.

One of the uses to which asbestos has been proposed to be applied in connection with warfare is as a coating for iron-clads. It was alleged by the inventor of the process that if asbestos were packed between the armour-plates it would arrest, or certainly minimise, the inflow of water after the penetration of a ship's side below the water-line. This has already been tried by the Admiralty, and an interesting account of the trial may be found in the *Army and Navy Gazette* Supplement (August, 1887). Although this first trial was decided to have been very successful, it does not seem to have been followed up; but should further experiments in this direction confirm its success, it is obvious that confidence would be raised in our fighting ships, by practically insuring them from becoming waterlogged in action.

Some of the uses to which asbestos is proposed to be applied are sufficiently astonishing. Who, for instance, could have imagined that a substance of such specific gravity as crude asbestos could have been manufactured into a cloth, available for aeronautical purposes, in which absence of weight is of such primary importance? Yet here it appears to be the one thing wanting to give success to that despair of aeronauts, military ballooning. Many years have now passed since scientific military men first turned their attention to aeronautics, and it is long since the War Department of the Government first authorized experiments to be made, with the view of utilising balloons in warfare; yet, notwithstanding all the time and money which has been expended, the result in the way of practical success has been actually nil. No use of balloons was made even in the late Egyptian campaign, which is suffi-

* *Jour. Soc. Arts.*, No. 1743.

cient to show that, so recently as that, English military men had no great faith in their availability.

The difficulties to be encountered in this direction are doubtless sufficiently formidable. Gas, it is clear, could not be carried into a hostile country or into remote and nearly inaccessible districts. Even if procurable at all, near the battlefield, it could only be obtained by a long and difficult process of generation, at the very time when speed and simplicity would be the main factors of success. Gas, therefore, being practically out of the question, it seems to have occurred to Mr. Spencer, the well-known balloon manufacturer, that it would be better to revert to the original conception of Montgolfier. The old-fashioned fire-ball, which acquired its power of ascension from rarefied air, produced by burning straw or something similar, was of course of far too dangerous a character, and had been productive of too many fatal accidents. It was necessary, therefore, to construct a balloon of some uninflammable material, and with the assistance of his friend, Mr. Fisher, the General Manager and Secretary of the United Asbestos Company of London, Mr. Spencer ultimately succeeded in so doing. A balloon was constructed, the whole of the lower part of which was formed of fine asbestos cloth, the remainder being of canvas, covered with a fireproof solution. A trial took place in the grounds of the Welsh Harp, at Hendon, which was afterwards repeated at Chatham, under the inspection of the Royal Engineers' Committee, and on both occasions with success. The experimental balloon, about 30 feet high, was suspended between two uprights, from which it hung down like a limp rag. It was of a cylindrical shape, having a deep zone at the equator, and a containing capacity of about 30,000 feet. A copper spirit lamp was attached to the neck, and no sooner was a light put to the spirit than the inflation commenced, the balloon being fully distended in a space of about five minutes. These trials have since been successfully continued in India, and the Russian Government has adopted the balloons for use in their army.

The immense advantage gained, by this method of inflation, over the tedious and difficult process of inflation by gas is sufficiently obvious, whilst it is at the same time apparent that the quantity of spirit requisite for an endless number of ascents could be carried about with the greatest facility. Another advantage is that, whilst the large volume of gas required for an ordinary balloon is in itself both deleterious and a source of danger, the rarefied air in the new fireproof balloon is perfectly innocuous. The balloon can be raised or lowered at will simply by turning the lamp a little up or down.

In further continuance of this part of the subject, that is, the application of asbestos to matters connected with warfare, the particulars of a very interesting experiment, which may have an important bearing on the carriage of explosive material in time of war, was given by Mr. Boyd, the late Manager of the United Asbestos Company's works at Harefield, in the paper* before referred to. He was alluding to the value of asbestos millboard as a lining for fireproof cases and deed-boxes, so as to convert them into portable fireproof safes. The matter, he said, was put to a practical test thus: two iron rails were supported on brickwork at a height of about eighteen inches from the ground, and underneath them a strong fire of wood shavings and chips was made, and when this had well burnt up, a deed-box filled with papers was pushed along the rails to the centre of the fire, where it was completely enveloped in the flames, remaining there for a space of twenty minutes. On the box being withdrawn it unlocked easily, and the papers were found in perfect preservation, being neither charred nor discoloured.

On seeing this result, one of the gentlemen present asked if the boxes could not be used for transporting gunpowder, or other explosive substances. A quarter of a pound of powder was then put in a small bag, and placed inside another box, which was pushed along the rails into the centre of the fire, to which fresh fuel had been added; and after the box had been exposed to the fire for twenty minutes the question natu-

* *Jour. Soc. Arts*, No. 1743.

rally arose how was it to be got off again? Mr. Boyd himself performed that operation, by means of a long iron rod and hook, after which the box was again opened and the powder found intact. The question was then asked by some one present who was not yet satisfied, "Why have the powder in a bag? Let it be laid on the bottom of the box loose." This was done, and the fire ordeal repeated, again with the same result.

The Société Française des Amiantes, availing themselves of Mr. Boyd's idea, recently announced as one of their specialities, the manufacture of bâches, or awnings for military waggons. And the Chalmers-Spence Company have also secured a large contract for the supply of mail-bags made of asbestos cloth.

As yet another instance of its applicability to purposes connected with warfare, it may be interesting to mention that I have lately seen it stated that the fibre would be of great value for use as lint in hospitals and on the battle-field. Of the intrinsic value of asbestos in this form I am unable to speak, having no knowledge of the mode in which its non-absorbent character is proposed to be overcome; but if it be a fact that it can be so used, in favourable comparison with the best lint, as stated, it is certain that its imperishable quality would be of great advantage, seeing that it could be used over and over again, only needing purification by fire after each time of using. Although, as has been recently remarked by the editor of the "*Engineer*," we may never reach the time when our undergarments shall be purified by fire, instead of by the laundress's art; yet, short of this, many uses now fulfilled by materials, the thorough cleansing of which cannot be secured without their destruction, may possibly be better served by asbestos.

If we now turn from matters connected with warfare, to those relating to man's perpetual battle with fire, we shall find that here also asbestos stands him in good stead. Chemists are constantly bringing forward incombustible preparations of the various alkaline salts and other chemical combinations, calculated to render textile fabrics and other materials fireproof;

but most of these salts evaporate, and frequently damage the materials they are intended to preserve. It has, consequently, been imperative to find a material capable of opposing a negative action to the persistently devouring element, and up to the present time no substance has been found so efficacious in this respect as asbestos.

Probably its earliest use, for this purpose, in building operations was in regard to roofing. The utilization in Canada of the non-fibrous variety of asbestos has already been noticed; and we are informed by a New York manufacturer that the daily make at his works of a special fireproof coating for a roofing material exceeds two miles in length.

In America, where asbestos is used far more largely than it is here, it is brought into use in a variety of ways for building purposes. In the building laws of New York, Philadelphia, Boston, and other cities, special insistence is placed on its use, and very material and expensive alterations are sometimes required, by the authorities, to be made in the fittings of public buildings, in regard to its more extended use for the protection of the public. This is in many ways rendered compulsory on every one desirous of obtaining a licence, for the erection of a theatre, concert hall, library, or indeed any public building of a similar character. So carefully framed are these laws in the city of New York that, in regard to such places as these it is enacted that "all the shelving and cupboards in each and every dressing-room, property-room, and other storage-rooms, shall be constructed of metal, slate, or some fireproof material. All stage scenery, curtains, and decorations, made of combustible material, and all woodwork on or about the stage, shall be saturated with some incombustible material, or otherwise rendered safe against fire, to the satisfaction of the Commissioners of the Fire Department of the city. The proscenium curtain shall be placed at least three feet distant from the footlights, and the proscenium opening shall be provided with a fireproof metal curtain, or a curtain of asbestos, or similar fireproof material; and said fireproof curtain shall be raised at the commencement of each performance, and lowered at the

close of said performance, and be operated by improved machinery for that purpose."

At the American Academy of Music, in Philadelphia, the underwriters offered a reduction of one per cent. per annum provided an asbestos curtain was placed in the house. The Fire Apparatus Committee then, it is reported, succeeded in perfecting "the only barrier of complete protection to an audience against fire in the world." This curtain, made of asbestos cloth (97 per cent. pure asbestos and 3 per cent. cotton), is 54 feet wide and 53 feet high. It is hung on wire lines, three-eighths of an inch thick, connected with a drum in the apex of the roof, and can be raised with ease by two men and lowered by one.

Again, after the disaster at the Ring Strasse Theatre, at Vienna, when attention was drawn to the great danger arising from the want of some certain and rapidly applicable means of separating the stage from the body of the theatre, the Roman Minister of Public Security issued an order that every theatre should be fitted with a fireproof curtain, capable of entirely isolating the stage from the theatre, and he indicated an asbestos cloth curtain as one that would meet the case. All the principal Roman theatres are now supplied with these curtains, the material having been furnished by the United Asbestos Company of London.

The same company make Booth & Fisher's patent asbestos double iron framed drop curtains, and Marius's patent asbestos double act drop; the former of these they have erected in Manchester, Birmingham, Edinburgh, and other places, and the latter at one or two theatres in London. These curtains have an air space between the two thicknesses of cloth, and are specially recommended by theatrical architects. The price of extra strong metallic cloth is 6s. per lb. Special precautionary measures are adopted by this company for preventing the iron frame from bulging in case of fire or sudden alteration of temperature. The asbestos cloth can also be used as an ordinary drop curtain, worked on rollers, and can be coated with asbestos paint, if desired, which effectually closes the pores of

the cloth, rendering the passage of smoke absolutely impossible.

Asbestos fireproof curtains are also in use in most of the theatres in America, and are there made a speciality of by the Chalmers-Spence Company, who furnish the curtains all ready to hang, made from the best quality of cloth and yarn, both manufactured from pure asbestos fibre.

As further illustrating the great importance attached to the extended use of asbestos in New York, for the purpose of preventing the spread of conflagrations, a company was some time ago established there, with the object of extending the use of asbestos in the shape of protection shields, either to be kept permanently fixed, or hung in such a way as to be capable of being promptly applied on sudden emergency. One of these shields was exhibited at a firemen's convention held at Rochester, New York. It consisted of a sheet of pure asbestos cloth about 20 feet square, supported on an iron frame; and for the purpose of testing it, a pile of pinewood, saturated with petroleum and tar, was built up on its windward side, and then fired. The heat from this fire was so intense that spectators could not approach within 50 feet of it, on the exposed side; on the side protected by the shield, the heat was so little felt that a construction of wood and glass placed close beside it suffered no injury at all.

In France many of these shield curtains are now in use, and they are found to be as effectual in preventing asphyxiation, from the passage of the clouds of smoke, as in staying the spread of panic by a sight of the flames, which are not intercepted by the old-fashioned iron arrangements.

The terrible calamity which happened some time ago at the Opera Comique in Paris, followed by that at Exeter, set men's minds running in the direction of providing greater security from fire in theatres. Several kinds of curtain, all involving the use of asbestos, were then contrived, the motive power being so arranged as to fully guard against the destructive force of a too rapid or unexpected fall, such as happened at Toulon.

The curtain made for Terry's Theatre by the United Asbestos Company is similar to that made by them for the Queen's Theatre in Manchester, its special qualifications being lightness, strength, and ease of manipulation. A special method of preventing the iron frame from "bulging" or altering its shape in case of fire, or sudden variations of temperature, is employed. By using weights not quite sufficient to counterpoise the curtain, the work of raising and lowering is very light. Combustible ropes may be employed, which, on being released by the action of fire or otherwise, will allow the curtain to descend of itself. Pockets are provided to catch the counterbalance weight in case of the breakage of the chain, so as to prevent personal injury, and friction rollers are put on the balance weights to ensure their free action. Similar rollers are also fitted on the curtain frame, to give freedom of action in raising and lowering. The hinging of the lower part of the frame, so as to admit of its being raised to the top of the proscenium opening when there is not sufficient room for a curtain of the ordinary make to be raised above the proscenium opening, is a valuable addition. The asbestos cloth is specially strengthened by a fine wire running through each asbestos strand, and is stretched across the whole of the framework, and fastened thereto by means of hoop iron and bolts. A double thickness of asbestos cloth may be used, if thought necessary, one thickness on each side of the framework, with an air space between. This was accepted on all hands as far superior to the old-fashioned iron portcullis, which was an absolute nuisance from the harsh grating sound it made when wound slowly up or down. Queen's Theatre burned August, 1890.

Mr. Henry Irving, in bringing to the notice of the public his proposals for a "New Safety Theatre," laid special stress on the necessity of shutting off the stage from the auditorium by means of an asbestos curtain, so that in the event of fire, which generally originates on the stage, its perils should be confined to itself; with the further necessity of providing an outlet for the smoke, which is sometimes even more disastrous in its effects than the flames.

Experiments were also about this time publicly made by Captain Heath to prove the fire-resisting qualities of a new curtain invented by him, the proceedings taking place within a specially-built hoarding, in Oxford Street, within which was erected a large model of the Drury Lane proscenium. The curtain in this case was made of asbestos and canvas, and was rolled on a block of wood placed underneath the front part of the stage. The sides of the model were made of iron plates and the front of wood. When certain catches were released counterbalancing weights came into action, and the curtain was run rapidly up from below. On reaching the top, it pressed tightly and automatically against the back of the proscenium, turning on at the same time a supply of water from a perforated pipe, which ran along the whole length of the top of the curtain, so as to keep it constantly wet. The arrangement of the switch, for communicating action to the curtain, was such as to turn on the water and close the curtain at the sides at will. A very severe fire test was employed which was pronounced to be highly successful, the universal opinion of those present being that, in its construction, the curtain was as simple as it was effectual for the purpose intended.

Another novelty in this line was shown to the public on the opening night of the "Jodrell Theatre." In order to show their desire of doing everything possible for the safety of the audience, the lessees exhibited, after the evening's performance, a new "Niagara" or safety water curtain. On the drop being raised, an illuminated sheet of water was seen to be descending from the flies, in such a way as completely to shut off the stage from the audience.

Since then the Baquet Theatre in Oporto has come to the apparently natural end of all such structures, namely, by a fiery death. The calamity was caused by the wings catching fire from a gas jet, whereby the whole of the stage scenery was almost immediately afterwards enveloped in flames, the furious progress of which it was found impossible to arrest. Here, then, was a striking instance of a holocaust being caused by

the want of such a curtain as has been described; for, had such a thing been available, the stage would have been at once shut off from the auditorium, and even if it had not been found possible to save the structure, the fire, at any rate, would have been localised for a sufficient length of time to have enabled the authorities to clear the building, and so have prevented the panic and horror which ensued.

And again, the Communal Theatre at Amsterdam has also succumbed to the devouring element. Here, notwithstanding that, as is reported, the major portion of the scenery "was painted with asbestos," everything was destroyed, including the costumes of the actors, and a library of 8,000 volumes.

It is worth while, perhaps, recording the foregoing, because there can be very little doubt that something of this kind will presently be made compulsory even in England, for use in theatres and music-halls generally. From the course matters are now taking in the United States, there is little doubt that the use of asbestos, in some form or other, will be made compulsory there for the shelvings and doors of public libraries and places for the custody of records, for sheathings between wooden floorings and below carpets, for hearthstones, for the linings of doors of elevators or lifts, for elevator shafts or stairways, and for the innumerable other places exposed to danger from flame or intense heat. The ease with which it can be applied, and the fact that it is absolutely impossible for flame to pass through it, makes it invaluable for purposes of this description. Where houses are constructed of wood, its non-conducting properties are found very useful, as it makes the house cooler in summer and warmer in winter than any other kind of sheathing.

In case of fire, in an adjoining house, it is quite possible the flames might destroy the outer covering; but, even then, the frame and interior would be as safe as if built of stone.

Before concluding this part of the subject, which is of such vital interest, it may be mentioned, as showing the extreme importance of the subject, that in Captain Shaw's book on "Fires in Theatres," a list is given of 112 theatres which had

been destroyed by fire down to 1875. The loss of life is not mentioned in the aggregate, but, by the burning of only three of the buildings mentioned, no less than 800 lives were lost and 123 adjoining houses destroyed.

M. Mauret de Pourville, writing on the subject, says that in the years 1867 and 1868, fifteen theatres in Europe and America were destroyed by fire; the value of the property so destroyed, irrespective of loss of life, being valued at from £640,000 to £680,000; and this, Captain Shaw says, is well within the mark.

The following startling list will show what fearful calamities have taken place since 1876, by fires in theatres, and the imperious necessity which has constantly arisen of at once adopting effectual methods of protection:—

FIRES IN THEATRES, ORIGINATING PRINCIPALLY ON THE STAGE, SINCE 1876.

Place.	Dates.	Lives lost.
Theatre des Arts, Rouen	April 25th, 1876	8
Chinese Theatre, San Francisco	October 30th, 1876	19
Circus Theatre, Madrid	November 13th, 1876	2
Mrs. Conway's Theatre, Brooklyn	December 5th, 1876	283
Cronstradt Theatre	January 9th, 1881	8
Opera House, Nice	March 23rd, 1881	150
Ring Strasse Theatre, Vienna (iron curtain was not let down)	December 8th, 1881	794
Briggs' Theatre, Moscow	January 7th, 1883	300
Temporary Theatre, Dervio	June 24th, 1883	50
Theatre Govi Sanuke, Japan	August 28th, 1883	75
Tinnevelly, India	July 28th, 1886	100
Temple Theatre, Philadelphia	December 27th, 1886	2
Opera Comique, Paris (official report)	May 25th, 1887	77
Exeter Theatre	September 5th, 1887	188
Grand Theatre, Islington	January, 1888	—
Bolton Theatre	January, 1888	—
Varieties, Madrid	January, 1888	—
Theatre Royal, Blyth	February, 1888	—
Union Square Theatre, New York	February, 1888	—
Music Hall, Leith	March, 1888	—
Oporto Theatre	March, 1888	160
Total		2,216

It is calculated that during the past eleven years 2,056 persons, or a yearly average of 184, have perished through fires in theatres, without taking into account the number of lives lost through panics.*

An extraordinary, or rather extreme, case of the use of asbestos as a protection from flames, has been recently reported from Canada, an account of which appeared in the London *New York Herald*, 25th August, 1889, which I give as narrated, being in no way responsible for the statements made. It appears that a gas well, at Ruthvan, having taken fire, the cap over the top of the pipe was so fixed that the escaping gas rushed out directly towards the ground, so as to make approach impossible, and consequently also the removal of the cap. All around the well the ground became so baked and heated that when cooling was attempted by a stream from a fire-engine, the water went up in a cloud of steam before it touched the ground. In this emergency the owners of the well offered a reward of $1,000 to any one who would remove the cap. A mining expert, named Marvin, undertook the job, and after many attempts to reach the well, made for himself a suit of asbestos clothing. In his first attempt, he had worn a heavy pair of cowhide boots, covered with wet cloths; but, before he got to the flames, the cloth had dried and burned away, and his boots were half burned off. So great was his hurry to escape that he dropped his cutting contrivance, and was dismayed to see it get red hot before his eyes. For his next trial he wore a pair of rubber boots, and inside these thrust his feet wound round with wet rags. Over these he put a heavy covering of asbestos. His asbestos coat was cone-shaped; his arms, sticking out through two holes in the cone, were wound round with several thicknesses of wet cloth, covered with a heavy coating of asbestos. His contrivance for cutting the pipe consisted of a very long and sharp chisel, fastened at right angles to an iron staff. His assistant, robed like himself, carried a long iron bar, on which was fastened a small farrier's hammer. His first stroke missed the chisel, and after two

* *Jour. Soc. Arts*, January, 1888.

more unsuccessful attempts he had to get out for air. Two hours afterwards, when he had recovered, he made another attempt, and this time the roar of the well, which could be heard three miles off, changed to a shrill whistle, and the cap blew off 100 feet into the air. Marvin, the narrator adds, was much scorched, but not injured so seriously as his assistant. He afterwards succeeded in fixing on another cap so as to shut off the flow of gas.

Notwithstanding the Munchausen-like way in which this story is told, there seems to have been a substratum of truth in it. Similar feats have already been performed, to the astonishment of the multitude, by so-called fire-kings or human salamanders. M. Pouchet,* Director of the Museum of Natural History at Rouen, mentions a case which he witnessed himself at Cremorne Gardens, where the man walked for several minutes in a long tunnel of fire, which looked, he says, like the most formidable flaming furnace one could imagine. In this case the tunnel of fire was arranged in the form of a cross, with an opening at the end of each of its arms. This tunnel, formed of a solid trellis-work of iron, the roof of which rose a little above the head of the performer, was covered with a heap of resinous wood. The man began his promenade beneath this at the time when the whole affair was a complete furnace, the flames of which rose to a considerable height, and the heat from which compelled the spectators to keep at a considerable distance from it. The garments of this incombustible being, M. Pouchet says, seemed to be of coarse cloth, and at the time when he entered the furnace they showed a vermilion red, but when he came out for the first time, to the surprise of every one, they had become as white as snow. The head of the experimenter was protected by a thick helmet furnished with glass eyes, and he seemed to carry in the folds of his dress an apparatus for yielding fresh air, by means of which he breathed in the midst of a combustion so intense that one entirely lost sight of him. Surprising as this exhibition then was, we should have little doubt now in what way the per-

* "The Universe," 3rd ed., p. 33.

former was protected by his skilfully made garments, from the heat to which he was exposed in appearance only, and by which the change of colour is fully explained.

The American Watch-Case Company, of Toronto, have their flooring protected by an asbestos covering, which recently saved their premises from destruction by fire. In connection with this part of the subject it may be added that various attempts have been made for the introduction of asbestos into the manufacture of lace curtains, dresses, &c., but I believe that the principal obstacle in the way of success, in this line, lies in the fact that in its present state, in the shape of curtains, for instance, it is found to be an obstinate holder of dust. This objection will, no doubt, be presently got rid of; and soon we may hope to have heard the last of those fearful scenes which have at times occurred from the firing of ladies' dresses at the footlights in theatres.

In regard to accidents from the footlights by reason of the dancers' dresses coming into contact with gas, it might be supposed that, by the substitution of the electric light, this danger would be obviated; but even the electric light, protected as the incandescence is, has its own especial source of danger, not the least singular of which may be noted in the following instance. At the Berlin Opera-House, one of the dancers, having inadvertently approached too near to a switch-board, her dress touched some metal parts between which a difference of potential existed. In the fabric of her dress metal threads had been interwoven which, bridging these metal parts, formed a short circuit and were heated by the current to such an extent as to set fire to the dress, whereby the dancer was much injured.*

The Chevalier Aldini's idea has been revived in Paris, the firemen there having been furnished with asbestos clothes. Immediately after this was done, it was reported in the papers that, on a conflagration occurring in the basement of a building there, the firemen arrived clad in their asbestos suits, and were thereby enabled to descend at once into the basement,

* "*Industries*," 2nd August, 1889.

where they extinguished the fire in a very short time, and so prevented what might have been a great calamity. The same course is now about to be taken in England, and the London firemen are to be protected in a similar manner; and there can be little doubt that this course will presently be universally adopted for the protection of the men engaged in saving life and property from destruction by fire. Nothing has yet been discovered that will equal asbestos for this purpose, as it will neither burn nor smoulder, and is as impervious to fire as well-made mackintosh is to water.

In a recent number of the *Canadian Mining Review* we are informed that, in the museum attached to the offices of that journal, there is to be seen a complete suit of clothing from helmet to shoes, such as is used by the firemen of Paris, dressed in which a man can walk into the hottest flame with comparative impunity. This suit was made and presented to the museum by Mr. Edward Wertheim, of the American Asbestos Company, Black Lake, and of Frankfort-on-the-Maine, Germany.

The following very interesting description of the "Appareil Aldini" is taken, by his kind permission, from Capt. Eyre M. Shaw's recent work on "Fire Protection," in which he gives it as his opinion that it is rather a matter of scientific interest than of practical usefulness. "In certain cases," Capt. Shaw says, "it may be indispensable to traverse the flames in order to reach some particular spot, and it was for the purpose of preserving persons who find themselves in such circumstances that the Chevalier Aldini, an Italian physician, thought of the apparatus which bears his name.

"This preservative apparatus consists of two vestments, one composed of a thick tissue of asbestos (amianthus), or woollen stuff, made incombustible by means of a saline solution, the other of a metallic cloth of iron wire, covering the first garment, and mounted with a helmet on the upper part.

"A person enveloped in these two garments can withstand the action of flames for some minutes without experiencing any dangerous effects, for on the one hand the external metallic tissue cools the flames, and on the other hand the internal

tissue transmits the heat very slowly, on account of the want of conductibility in the substances of which it is composed.

"Aldini's apparatus dates at least from the year 1825, but notwithstanding the good results which it has shown in the numerous experiments to which it has been submitted, it has never been adopted to any considerable extent, either because the circumstances in which it could be really of service are much too rare in comparison with the expense of its manufacture and maintenance, or because—as happens with a number of inventions—it presented, in serious practice, considerable inconveniences, such as rarely occur in experiments for mere show, where everything is generally arranged for the success of the operation.

"The following is an account of one of the experiments made in Paris in 1829, by some *sapeurs pompiers*, or firemen, with Aldini's clothing on:—Two piles were erected of thin wood, covered with straw, ten yards long, two yards high, and distant from each other about a yard and a half; two lateral openings allowed the firemen to go out from the flames, if they were compelled to do so, and in other ways facilitated the experiment, which consisted in traversing half the length of the burning heap, going out by one of the lateral openings, and entering again by the opposite end, and then repeating the same experiment from the other side of the heap. The four firemen who were to make this trial were clothed in the new garment of metallic tissue; two carried besides a clothing of asbestos (amianthus) over a cloth garment, rendered incombustible by borax, alum, and phosphate of ammonia; the two others had a double clothing of prepared cloth; each man had boots of asbestos, and under the foot a piece of cardboard of that substance; and one of them carried on his back a child, ten years of age, whose head was enveloped in a helmet of asbestos. The firemen penetrated together into the interior of the double pile of flames, and, walking slowly, traversed it several times. At the end of sixty seconds the child enclosed in the basket cried out, so that the man who was carrying him was forced to retreat precipitately. They made haste to take

out the child, who had in no way suffered; his skin was fresh, and his pulse, which beat 84 before the experiment, was only 96 after it. He could, without any doubt, have remained much longer in this wrapping were it not for the fear which seized him, and which was caused by one of the straps supporting the basket having slipped a little on the shoulder of the fireman who carried it. The child, at the sight of the flames which roared below them, thought he had been thrown into them. A few minutes after he was as merry as usual, and felt no uncomfortable sensation. The fireman who carried the child had before the experiment 92 pulsations a minute, and after it 116. The three others remained in the flames two minutes and forty-four seconds, and came out without having experienced anything except a sharp heat. The pulsations were before 88, 84, and 72 a minute; and after, 153, 138, and 124 a minute. The flame was continually fed with straw thrown upon that which was burning. There was very soon formed an enclosure of fire, in which the firemen were shut up, and as a portion of the straw scattered on the ground threw up a flame which at times enveloped their legs, it was certain that the bodies of the men were exposed to the direct action of the flames. At a distance of more than six yards from the focus of the fire, the heat was so intense that none of the numerous assembly could remain there. In other experiments the firemen were furnished with large shields, which they made use of to keep back the flames. It is obvious that such an apparatus as this could be of very little use for general work."

In concluding this part of the subject it may be worth remarking that in Barnum's recent Exhibition in London of the destruction of Rome by fire, surprise was constantly expressed at the wonderfully realistic way in which such apparently substantial buildings, as those erected in the representation of the Eternal City, were nightly destroyed in the conflagration. Here the whole secret lay in a liberal use of asbestos combined with skilful combination of chemical effects.

CHAPTER X.

MISCELLANEOUS APPLICATIONS OF ASBESTOS.

COLD STORAGE—Retention and Exclusion of Heat—Deck Cabins—Filtration—Filter Papers—Water Filters—Filtration of Sewage—Pipe Joints—Furnace and Kiln Linings—Crucibles—Gas Stoves—Open Fires—Fletcher's Stoves—The Leeds Stove—Plastic Stove Lining—Asbestos Paint—Insulation-Paper for Battery Plates—Gloves—Aprons—Stove Piping—Rope—Ladders—Rods in Dye-Houses—Lamp Wicks—Gas Shades—Wall Papers—Writing Paper—Cigarette Papers—Tobacco Paper—Pulp—Boards—Cork Soles—Moulds for Type—Silversmiths' and Jewellers' Moulds—Covering for Woodwork—Fireside Rugs.

FOR cold storage buildings and refrigerating chambers, the non-conducting properties of asbestos render it simply invaluable. For the preservation of meat, and all kinds of provisions brought from distant lands, specially-constructed ships containing the necessary refrigerating apparatus and chambers are in universal use; and buildings of considerable size are in existence in all populous places. These are mostly underground in London, but in New York and elsewhere many buildings are specially erected for the purpose, and these mostly have double walls surrounding the cold chambers with some kind of non-conducting material between, by way of lining, for which asbestos is largely used.

In order to show its value in the exclusion of heat, Mr. Boyd cites the case of a Channel steamer, the owners of which wished to have the boiler covered with asbestos composition. The engineer's berth, being quite close to the boiler, was unpleasantly warm even in winter; but, after the boiler had been

covered in with an application of the composition, two inches thick, that functionary had a different tale to tell, the heat being so effectually confined to the boiler that the change made his berth unpleasantly cold. Again, in the case of the rebuilding of a seamen's floating chapel at Genoa, the old chapel, having been erected on the deck of a hulk, was found to be too expensive on account of the reparations frequently rendered necessary by the extremely high summer temperature. It was desired that the new chapel should be built of iron; but fears were expressed that, when exposed to the summer's sun, the roof and sides would get so hot as to make the temperature inside unbearable. Mr. Boyd, therefore, suggested that the space between the outer skin and the inner boarding should be filled with pulverized asbestos. Accordingly, this space, of about 1¼ inches, up the sides and over the ceiling, was tightly rammed with asbestos powder; and the result was that, while the outside temperature stood at 100°, the inside temperature, the doors and windows being kept shut, did not reach 70°, and was, therefore, in comparison, deliciously cool. Mr. Boyd consequently suggests that the deck cabins of steamers, passing through the Suez Canal, or navigating the Red Sea, should, by similar means, be made more comfortable for the passengers. Probably this object could be as easily attained by the use of "Superator," described in a previous chapter.

In the beetroot sugar refineries of France, Germany, and Austria, fine asbestos cloth is in universal use for filtering the saccharine juices. It is used also in chemical laboratories for straining and filtering acids and alkalies, which would quickly destroy any ordinary filtering paper; and it is specially useful when the liquid to be filtered is of a caustic or strongly acid nature, or where it may be desirable that the filter, with residue, should be ignited without consuming the filter, or where the residuum is to be dissolved off the filter by acids or other solvents. Asbestos filter bags are better fitted for this purpose than those made of any other material, they last longer, retain the heat better, and are more easily purified.

In many cases a very finely-divided asbestos is desirable. This is accomplished by a process recently patented in Germany by Fr. Breyer, of Vienna. The asbestos is first coarsely ground, and then mixed with some granular crystalline carbonate, which must be soluble in acids. The carbonate should possess a hardness between 3 and 4, 5, according to the mineralogical scale. The mixture is ultimately ground together in a mill, and then the mass is treated with an acid until the carbonate has been dissolved out. The escaping carbonic gas causes the asbestos fibres to be loosened and disintegrated from each other, so as to make the mass porous. It must be thoroughly washed with water before being used.

For filtration purposes generally, asbestos has proved to be so eminently adapted, by reason of its peculiar properties enabling it to resist the action of alkalies and acids, that, either in the form of cloth or finely carded fibre, which, when fouled, can be easily cleaned by hot water or steam, it forms a material adjunct to the filtering media in all the more important filters now used. All filters are modifications of the simple principle here shown, the object being the purification, by separation, of liquids from the substances held in suspension in them through the pores of the media used, which must be sufficiently fine to retain or keep back the solid matter. The filtering medium may be any substance of a sufficiently spongy or porous nature to allow of the free percolation of the liquid, the pores at the same time being sufficiently small to render it limpid or transparent.

Filter.

If a large quantity of liquid has to be filtered, or if the substance is too viscid, or for acids or alkalies, a funnel of asbestos cloth suspended by a hook is found useful.

In other forms, rapidity of filtration is the point aimed at. To secure this, regard must be had to the porosity of the filtering medium, the extent of the filtering surface, the relative viscidity or mobility of the filtering liquid, the pressure or force by which the liquid is impelled through the

pores of the filter, and the porosity and fineness of the substances it holds in suspension.

The various filtering media now commonly used, with the mode of applying the asbestos, will be sufficiently seen from the following examples:

Asbestos Cloth Filter Suspended.

In M. Maignen's "Filtre Rapide," the apparatus consists of a hollow perforated cone of earthenware over which a specially woven asbestos cloth is stretched. Canvas or felt an inch thick was at first used for this purpose, but it was found that with soft rain water, containing ammonia, this felt became as rotten as wet blotting paper. Asbestos was accordingly suggested, but it was at first supposed that this would be too expensive, and it was some considerable time before a pure asbestos cloth could be made, of exactly the right porosity, to arrest the fine filtering medium which is used in this apparatus to purify the water chemically; but so successfully has this at length been accomplished, that Mr. Maignen anticipates that presently asbestos cloth will take the place of sand in the purification of the water supply of London. In this filter a layer of finely-powdered carbo-calcis is automatically deposited on the outside of the asbestos cloth (which is stretched over an earthenware cone), by being mixed with the water first put in; and to cleanse the filter all that is required is to deposit a fresh supply on the asbestos cloth.

In Judson's filter, the medium employed is said to give off minute particles of oxide of iron, which necessitates the use of a straining apparatus. To effect the required object, porous blocks or slabs of carbon, or silicates of various kinds, are used; but as these sooner or later get clogged, they have to be cleaned by brushing or scraping, or by replacing the block by a fresh one, in doing which it is difficult to prevent particles from passing round the joint. This difficulty is surmounted and

perfect mechanical straining effected by substituting a layer of carded asbestos fibre for the block.

In Creswell's asbestos carbon filter (Parker's patent Niagara) the inside is quite plain, except for three or four projections, which are rounded below but shouldered on the top. These projections support a perforated stoneware tray, which carries the filter bed and unfiltered water; and any number of these trays may be used by placing them one above the other. The edges of the trays and the sides of the cistern are rendered waterproof by a flexible closely-fitting ring, so as to prevent the water, running between, carrying with it small particles of the filtering material. Whilst the upper bed detains the rougher particles of dirt and any organic matter, the water is effectually purified by the asbestos tray and the lower bed.

In Cheavin's "New Patent Removable Plater Filter," the construction is of so simple a character that the whole can be taken to pieces and the purifying medium renewed within a few minutes, whilst nothing comes in contact with the water but the stoneware, the "idiocathartes," and the asbestos cloth. The shape of this filter enables a large amount of the purifying medium to be used, over which is spread a screen of asbestos cloth, which arrests all the impurities before they are brought into contact with the idiocathartes.

Lipscombe's filter is noticeable for the simplicity with which the filtering material can be renewed. The construction is very simple, being one perforated earthenware cylinder within another, each covered with the United Asbestos Company's special asbestos cloth, with the filtering material in the intervening space.

In the filtration of sewage, and in the purification of foul gas in connection with sewer traps, and for ventilating and deodorizing manholes for cesspools and sewers, the asbestos fibre is saturated with deodorizing liquids which render the escaping gases harmless. The system of deodorizing sewer gas, formerly adopted, was to cause the gas to rise through charcoal, but the impurities soon clogged this up and prevented the passage of the gas. Messrs. Adams & Co., of York, sug-

gested a new mode, by placing over the opening rising from the sewer a hood of galvanized wire interlaced with asbestos yarn, spun in such a way as to have good capillary action, the ends of the yarn being dipped into a liquid disinfectant. When the fibres are saturated, a disinfecting screen is formed, through the meshes of which the gases rise, and in their passage through they become purified and rendered innocuous.

For forming the joints of pipes exposed to the action of moisture, and for man and mudhole doors requiring frequent removal, asbestos woven cloth is very largely in demand. In these cases asbestos millboard, which is the cheapest form of jointing material, is comparatively worthless, if, indeed, it is not absolutely objectionable, from its permeability to water, which soaks through and attacks the iron of the bolts, and it was, therefore, necessary to devise a combination which would effectually resist the heat and damp. This is provided in what is known as Asbestos and India-rubber woven sheeting, which is made in any thickness, and is supplied either in sheets cut to the required shape, or in a tape 1 in. to 2 in. wide, which can be cut to length and bent to circle or oval without puckering. When all other materials have failed to give satisfaction, this has answered admirably, and in the case of manhole and mudhole doors and feed-water pipes the joint can be broken twenty times without requiring renewal of the strip.

The United Asbestos Co. supply "United asbestos rubber woven sheeting," which is now being superseded, for high pressures, by their asbestos-metallic "Victor" woven sheeting, in which a fine wire runs through the centre of each asbestos thread. Great durability is insured by the use of asbestos cloth, the requisite elasticity being imparted by a coating of india-rubber which fills the pores of the cloth and renders it waterproof. The "United asbestos rubber woven tape" is composed of the same materials, and being easily bent into position, without puckering, a joint can be quickly made without waste, and steam can be turned on as soon as the joint is screwed up. For manhole and mudhole doors, which have to be frequently opened, it is simply invaluable.

Being one of the most refractory substances known, asbestos is used in a variety of ways for the lining of furnaces. When the metal and fire are together, as in the cupola, or blast furnace, it constitutes a most enduring and heat-confining lining, and is particularly adapted for use where the metals or ores contain sulphides, as sulphides have no effect on asbestos. As linings for furnaces and kilns, and for use in the manufacture of crucibles, a patent has been granted for an improved refractory material composed of a mixture of the aluminous asbestos from Natal with fire clay, in the proportion of one part of asbestos to four of fire clay. Both are finely pulverized and formed into the desired shapes, while in a plastic state. The patentee states that if a material of greater fire-resisting properties is required, the worn out "saggers" are pulverised, and a fresh supply of fire clay equal to double the amount of powdered "sagger" is added. When this material is exposed to extraordinary heat it does not crack; but, on the other hand, it tends to fuse and bind its particles closer together. Another convenient property of the material is that it is capable of resisting the attacks of atmospheric and chemical substances, such as damp, sewage, &c. This special form of asbestos is stated to be additionally valuable both on account of its cheapness and the convenient form in which it is imported.

Perhaps the most popular conception of the use of asbestos is that where it figures in gas stoves; but there are so many varieties of these, and generally they are so well known, that little need be here said about them.

From an Englishman's point of view, engendered by long habit and the damp and chilly climate in which he lives, there is nothing to which he attaches so much importance as the luxury of a visible fire. The stoves and warming apparatus mostly in vogue elsewhere, excellent as they are in their way, are simply nothing to him in comparison with the comfort and cheerful appearance of his open fire, even when, as is only too frequently the case, the unscientific construction of his fire-place causes nine-tenths of the heat from the fuel to be lost in

the chimney. When living in Canada, in rooms comfortably warmed by the stoves in use there, on re-entering from the keen air outside, I always felt an irresistible desire to kick open the stove door and revel in the cheerful blaze, and enjoy the sight of the flames rippling over the logs. It is only by very slow degrees that a more scientific manner of warming houses or rooms in England can make its way, such is the obstinate conservation of the people and their disinclination to move out of the old-fashioned ways of their fathers. For sometime past, however, practical men have been drawing attention to this subject, with the praiseworthy object of showing how to obtain the maximum of heat from a minimum of fuel, reserving at the same time the luxury of the visible fire. There is more than fancy in this, because heat, radiating directly from glowing coals, passes through the air without modifying its temperature in any important degree; consequently, coming in contact with the person it imparts warmth to the body, whilst leaving the air comparatively cool. For public rooms, or places which people simply pass through, warm air stoves are both economical and satisfactory, but for places where people remain seated for any length of time, the comparatively low temperature of the floor and walls, which always occurs when warm air alone is used, combined with the effect of the warm air on the lungs, causes an unpleasant feeling, which is not felt when moving about. Unless, therefore, the difference between radiant heat and warm air be taken into consideration it is not possible properly to appreciate the comparative value of the different systems. Registration by thermometer is no guide to comfort, and is useless in estimating the value of radiant heat. Acting on these principles Messrs. Fletcher, of Warrington, have produced an asbestos gas-fire respecting which the committee of the Gas Institute state, in a report issued by them, that in regard to floor temperature the highest recorded at the floor level, which may be taken as synonymous with comfort of body and warm feet, was obtained by it. Gas used in this way costs less than coal for making a room comfortably warm.

Another good stove is the "Leeds," which was shown at the Brussels Exhibition. Here the flame is made to impinge on an asbestos block, which it brings to a white heat, insuring complete combustion and the total absence of noxious vapours. In this case the heat is thrown, by direct radiation, on to the floor, which is undoubtedly the most hygienic way of heating rooms.

"Plastic stove lining" is composed of asbestos or other fireproof material prepared in the form of a cement, so that it can be used for the lining of cooking and heating stoves, as well as the fire doors of boiler furnaces, &c.

In regard to the fibre used in gas fires, the best long silky fibre is worth 10s. per lb.; 2nd quality, 3s. 6d.; and the asbestos fuel 6d. per lb., or 32s. 6d. per cwt.

The demand for asbestos paint is continually increasing. It is used largely in the Houses of Parliament and other public buildings, as it was at the several Exhibitions at South Kensington. The whole of the buildings at the "Healtheries" were coated with asbestos paint supplied by the United Asbestos Company; and, in his presidential address to the Institute of Civil Engineers, Sir Frederick Bramwell stated that these buildings owed their escape, during an outbreak of fire, to the fact that their walls were covered with asbestos paint. And at the "Fisheries" in 1883, the Prince of Wales, as Chairman of the general committee, announced that, owing to the use of asbestos paint, they had been enabled to insure the buildings and contents at fifty per cent. less than usual.

50 lbs. weight of asbestos paint is sufficient to coat about one hundred square yards of wrought timber primed in the usual way: for unwrought timber the quantity must be increased according to the condition of the wood. On rough wood one coat will offer great resistance to flame.

The woodwork in buildings constitutes, of course, the greatest danger from fire. Every one knows the difficulty of lighting a fire without wood; neither paper nor shavings are of any use, as these will only blaze up brightly and then burn out without firing the coal, though they will readily light up the wood which

will inflame the coal. When, therefore, the woodwork of a building catches fire there is great danger, because the flame emitted is a clear flame of great penetrative power, which is the cause of the rapid spread of the fire from the starting point to staircases and passages affording communication from room to room. If all wooden fittings could be replaced by iron, many a fire would burn itself out, and ample time would be afforded for the engines to arrive before the conflagration could assume unmanageable proportions. But in the great majority of cases iron fittings are an impossibility, and there is no alternative to the use of wood.

Many attempts, consequently, have been made to render wood uninflammable. So long ago as July 1871, Mr. Frederick Ransome experimented in a wooden shed partly painted with siliceous paint, which was set on fire. The unpainted portion was completely destroyed, while that which was protected by the siliceous covering escaped ignition, and although deeply charred never took fire at all. The composition of the paint was analogous to that of Ransome's patent stone; it consisted principally of a mixture of pure silex and soluble silica, converted into an insoluble siliceous covering by an outer coating of chloride of calcium. Although this invention promised well at the time it never came into extended use. But the idea of covering wood with a fire-resisting surface having been published, it was taken up and improved upon by others. The refractory quality of asbestos being well known, Mr. Thaddeus Hyatt, who had already spent much pains upon developing the industrial uses of asbestos, endeavoured to turn it to account in the protection of buildings against fire in the form of a coating of cement. He ground the shorter and less valuable fibres into a slip or paste, analogous to porcelain slip, and combined it with gelatinous silica, either alone or in conjunction with magnesia, baryta, alumina, or lime.

In 1881, Mr. E. G. Erichsen, of Copenhagen, who had been connected with the earlier experiments at the works of Mr. Ransome, brought out a new protective composition in which there is likewise a large percentage of asbestos. When in-

tended for use as a paint or enamel it is composed of a siliceous solution, pulverised asbestos, metallic oxides and chalk, the asbestos forming 10 to 20 per cent. of the whole. Applied as a paint, it forms a fireproof enamel, capable of resisting a white heat. It is worked, upon brickwork and woodwork, with an iron trowel or wood plate covered with felt; it can be laid on in a thicker or thinner coat as may be desired, and can be cleaned from time to time with hot water.

The latest fireproof paint is the invention of Mr. C. J. Mountford, of Birmingham, whose patents have been acquired by the United Asbestos Company. This is simpler in its composition than the last, and consists of asbestos ground and re-ground in water, aluminate of potash or soda, and silicate of potash and soda. When it is to be exposed to the weather it is combined with oil, driers and gummy matters, and in some cases with zinc oxide or barytes. But by far the best material for a fireproof paint is steatite, which, like asbestos, is a silicate of magnesia.

For insulation purposes asbestos is much in use by electrical engineers in the form of millboard, in the construction of dynamos; and cables and leads, covered with plaited yarn, have been adopted in several installations. It is also made into tubes, fitted into sockets, for joining the lengths, and with elbows for turning corners. The advantage of an insulator, formed from a material unaffected by heat or damp, is plain enough. Cheapness of production, however, is very essential, as in this class of work asbestos is brought into competition with other materials, which though not possessing all its advantages, are more easily procurable and require less special adaptation in their manufacture.

A special quality of asbestos paper is made for wrapping battery plates in; and gloves are made of asbestos cloth for holding red-hot crucibles;* others of a lighter make, lined with rubber, enable the engineer to handle the wires with comparative impunity. Another non-conducting material is supplied for the wires, which, whilst preserving their perfect in-

* Watt's "Dic. Chem." Art. Asbestos.

sulation, guards them equally against risk from fire and damage from contact with water. Tubes are made for providing a non-conducting covering for electric wires, both fire and water-proof, which preserve a perfect insulation.

For the special class of work which relates to fuses and incandescent circuits there seems, at present, to be some difficulty, brought about by the contact of asbestos with copper; the former, for some unexplained reason, appearing to exercise an injurious effect upon the latter. The fuses for high tension currents used for transformers are made of copper wire, passed through sheets of asbestos, so as to break the arc when the fuse goes. In this application it may be that asbestos exerts some peculiar corrosive action on the copper wire, as, at the points of contact, the wire turns green and soon eats away.

Again, the non-conducting and fire-resisting properties of asbestos render it invaluable to iron and steel manufacturers for lining or covering the tubes employed to convey hot air from the stoves to the furnaces or cupola.

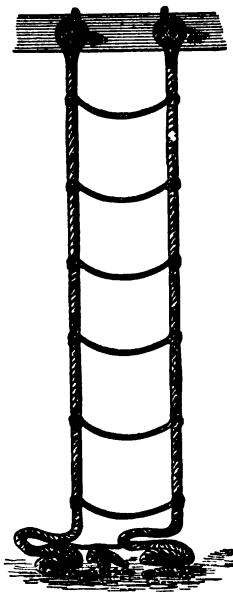
Its usefulness also for firemen's and stokers' aprons, or, indeed, for any one working in dangerous proximity to fire or sparks, as well as for salvage blankets, needs no comment.

In the United States an improved stove piping is made from asbestos, which in appearance exactly resembles cast iron. These have the additional valuable properties of extreme lightness, combined with great strength and a capability of ornamentation unobtainable with the cast-iron pipes mostly in use; paint, in the case of the asbestos pipes, not scaling off under heat as it will do in the case of ordinary iron pipes, nor will it even blister under the most trying circumstances. The manufacturers of these pipes claim for them that they combine the strength of steel with the lightness of paper.

Capability of ornamentation is a noteworthy feature in all similar cases, as well as in floor cloths, panellings, and such like goods which are all capable of being made ornamental and of being coloured and brought out in shades and patterns so as to harmonize with their surroundings. Composition mouldings, in imitation of stone, wood, metal, or bronze, old oak or

other carvings in relief look remarkably well, and, if treated with dark distemper oakstain and oiled, singularly resemble the genuine carved oak, whilst possessing the additional advantage of being fireproof.

Possessing great tensile strength, and, as we have seen, being entirely unaffected by heat, asbestos rope at once asserts its applicability for a great variety of purposes, such as sash-lines and ropes for fire-escapes. Such a ladder as is here represented fitted with gun-metal heart thimbles, to attach to hooks or fasteners, will sustain the weight of two or three men with perfect impunity. The weight of a fifty-foot ladder of this description is about sixteen pounds only. It is related in the history of a man of fashion, a millionaire who died not long since, that he was accustomed to say when speaking of danger from fire, that he would never go to bed in a strange house without having an apparatus of knotted rope affixed to a ring in the wall, so that he might lower himself to the ground on an emergency. On one occasion when asserting this, he was asked, What if the rope itself took fire? Had he known of its existence, he might have replied, "Let it be an asbestos rope."



Asbestos Rope-ladder.

In dyeing and printing cloth it is frequently necessary to hang the fabric in loops from parallel rods for exposure to steam, air or ammonia. In order that it should hold upon the rods, without straining or slipping, rope or strips of cloth are usually wound around the poles, but this does not remove, although it mitigates, the difficulty, because the heat and corrosive action of the vapours will rot any covering, the first notice of the deterioration being generally the appearance of small pieces of rod-covering among the cloth which is in pro-

cess of finishing. Asbestos rope and cloth are now largely manufactured and used for this purpose in the United States, with very beneficial results.

Indestructible wicks are used in some forms of safety lamps, their cost being slightly above that of ordinary wicks. These are specially useful to all who make use of mineral or heavy oils, as they obviate the disagreeable task of daily trimming: an asbestos wick can be used for twelve months without any trimming at all. It is composed of the finest asbestos fibre, made in the form of a strong soft wick, which can be used, if desired, as a packing, wound or packed round small steam or other valve stems, and for many other purposes.

A lamp which can be used as a night lamp, fire lighter, or for cooking, has been recently patented as "The Devonshire Everlasting Candle." It consists of an outer casing of metal, glass, or other material, with a perforated bottom; and is nearly filled with a porous earthy substance, which the inventor calls "Egyptian clay," by which the oil is absorbed. The indestructible wick is made of slag-wool and asbestos fibre. To charge the lamp it is placed on a saucer or plate containing the oil, which is drawn up and absorbed by the porous material within.

Incombustible and non-arsenical asbestos gas shades are naturally much less risky than the ordinary paper shades.

Asbestos is also manufactured into wall and ornamental papers; coloured wall papers, practically indestructible by fire, can be had in great variety. After severe heat tests, these retain their colourings and letterings as clearly impressed and as visible as before. They show up colours in a brighter fashion than ordinary paper, and are therefore specially useful for theatrical side scenes.

Jagnaux (p. 552) speaks of its use in a similar way in France, saying:—"On prépare avec les débris d'amiante, ainsi qu'avec une variété cotonneuse de cette matière, une pâte avec de l'eau et du silicate du soude, et cette mixtion peut remplacer la couleur à la céruse ou au blanc de Meudon pour la peinture des châssés employés pour les décors du théâtre."

Asbestos papers for writing and printing are a great desideratum. We have already noted Dr. Bruckmann's experiments in this direction; but actual successful experiment in the fabrication of paper has been greatly thwarted by the natural affinity of asbestos for water. Few kinds of asbestos are suited for paper making, and, even when the right quality is obtained, special treatment is necessary. A patent for asbestos paper-making was granted in 1853, and in this case the pulp was mixed with alum, with the object of producing a fairly indestructible paper. The low price of some descriptions of the mineral, coupled with its heat-resisting and low heat-conducting powers, have led to constant experiments in America for its use in paper-making. Most of the papers thus made contain only about one-third of their weight of asbestos. Some of them will burn with a flame, leaving a white residue which, if the sheet be carefully handled, will retain its shape, the writing, with common ink, being perceptible even after the organic substance of the paper is consumed.

A very good class of asbestos paper was some time ago manufactured in Paris, but the principal defect of all asbestos papers is the natural tendency to work up more like blotting paper than ordinary writing paper. It will be readily seen that, when the difficulties incident to its manufacture are successfully overcome, how invaluable such papers would be for bankers' and merchants' books, registers, deeds, and permanent records of all kinds. A good deal of the inherent difficulty has now been surmounted, but still the best writing paper produced is too tender, and any writing upon it is apt to disappear if the paper be subjected to a red heat.

Some time ago a firm in New York had its price lists printed on asbestos paper, and at the present time the Chalmers-Spence Company produce a class of paper as capable of receiving good impressions from type as any in use in modern books.

Cigarettes were recently sold in London having a case of asbestos paper, the object apparently being to get rid of the objectionable burnt paper in ordinary cigarettes. In this case

the tobacco burnt out leaving the paper intact; but as these cigarettes have now disappeared it is presumed they met with no success.

The last new thing in this line is a "tobacco paper and compound tobacco asbestos mixture." The inventor makes paper from tobacco, rendering it more fibrous by adding a percentage of asbestos. The paper is cut up like cigarette paper, and a number of these leaflets are put up together in book form. To use it you take out a leaf and roll it up between your fingers, and it is then ready for smoking. As asbestos has neither taste nor smell, it does not interfere with the flavour of the tobacco, whilst the evil effects of smoking paper are obviated. The mixture is so made up that the asbestos is not observable in the mixture. It is very cool to smoke and consumes the nicotine in the tobacco, whilst it burns right down to the bottom of the pipe. A pipe smoked with this tobacco-asbestos is said to be always dry and to leave no filthy moisture in the stem.

In a recent number of *L'Industrie Moderne* there appeared an account of a new process invented by a Mr. Ladewig for manufacturing pulp and paper from asbestos fibre, which he asserts will not only resist the action of both fire and water, but will absorb no moisture; this pulp, he says, may also be used as a stuffing and for the joints of engines. He further proposes to use it, in the form of a solid cardboard, as a roofing material for light structures. The process of manufacture consists in mixing about 25 per cent. of asbestos fibre with about 25 or 35 per cent. of powdered sulphate of alumina. This mixture is moistened with an aqueous solution of chloride of zinc. The mixture is washed with water and then treated with an aqueous solution of ammoniacal gas. The mixture is again washed, and then treated with a solution composed of one part of resin soap and eight or ten parts of water mixed with an equal bulk of sulphate of alumina, which should be as pure as possible. The mixture thus obtained should have a slightly pulpy consistency. Finally, there is added to it 35 per cent. of powdered asbestos

and 5 to 8 per cent. of white barytes. This pulp is treated with water in an ordinary paper machine, and worked just like paper pulp. (*Vide post*, p. 209.)

In order to manufacture a solid cardboard from asbestos which shall be proof against fire and water, and capable of serving as a roofing material, sheets of common cardboard, tarred or otherwise prepared, are covered with the pulp. The application is made in a paper machine, the pulp being allowed to flow over the cardboard.

Boards can be made in any thickness from that of the thinnest card to heavy shelving, fit either for partitions in safes, or for use in large libraries. I have been informed by a Canadian manufacturer that, in his early attempts to manufacture millboard, he could not get it stiff enough and tried a mixture of cotton fibre; but, after exposure to fire, the board again became limp, and that he was ultimately successful by the use of potato starch, (mixed to about the consistency used by laundresses,) stirred up with the pulp, and that then, after the application of fire to the finished board, it remained firm and stiff.

Asbestos has also been proposed to be used as an inner sole or lining for boots and shoes, with the object of keeping the feet warm in winter and cool in summer, the material possessing the double advantage of being at once a preserver of heat and a protector from cold. A patent has recently been taken out for this, and I have now a pair of asbestos socks in my possession. They are formed of a thin sheet of asbestos paper enclosed in a calico cover, and are intended to be used by slipping the so-called sock into the boot, like an ordinary cork sole.*

Respecting the use of asbestos in type foundries in France, Jagnaux says (p. 552): "On se serte dans l'imprimerie du

* The Laplanders gather what is called the "Lapp Shoegrass," of which there are two varieties, the *Carex ampullarea* and the *Carex vesicarea*, both of which grow near pools. This they place and wear in their shoes, it having the peculiarity of retaining heat, and keeping the feet so warm that cold can be defied.

papier d'amiante pour la confection de certaines moules dans lesquelles on coule les caractères typographiques. Ces moules ou flans se font tout simplement en encrustant le cliché dans un papier compressible. Lorsqu'on emploie le papier d'amiante on peut se servir une vingtaine de fois du même moule, tandisque ceux qui sont faits en papier ordinaire sont carbonisées après la deuxième ou troisième opération. Le papier d'amiante sert aussi à doubler les decors de théatre (marouflage) qu'il met aussi à l'abri de l'incendie. On emploi également l'amiante pour envelopper les cables télégraphiques ; en effet, il presente sur la gutta percha l'avantage d'être infusible, tandisque cette dernière substance commence à fondre vers 50°, c'est-à-dire à une température qu'on observe frequemment dans le sol, en Algérie par example ; aussi notre armée d'Afrique a-t-elle adopté ces enveloppes d'amiante."

Special asbestos moulds are manufactured for a variety of purposes by the Chalmers-Spence Company, such as for silversmiths' and jewellers' soldering work ; a few of which are mentioned here, as specimens of the adaptation of asbestos to this particular class of manufacture. One of them is a patent watch case and jewellery soldering block.

This block is a homogeneous body of porous asbestos, which will neither break, crack, nor disintegrate under the most intense blowpipe heat, and is at the same time of such a refractory nature that the block may be held in the hand with perfect safety while one end is in the blowpipe flame. It is of so porous a character that binding wires or pins can be readily inserted, whereby small objects of jewellery can be easily and quickly secured to its surface ; whilst being indestructible, the block can be used over and over again.

The block specially made for watch-case manufacturers is in cup form and of the proper size to hold a watch case. With the cup, but separate from it, is a handle provided with a metal frame or socket, on which the cup is placed when ready for use ; and with each block a box of asbestos paste is furnished for protecting the delicate parts of fine work, in using which the fibre is moistened, and the jewel or case embedded

in the paste. Another block, made for a similar purpose, is shown thus :

Asbestos Watch-case Soldering-block. (The Chalmers-Spence Company.)

Professor Tyndall explains that the transmission of heat is powerfully influenced by the mechanical state of the body through which it passes. Pure silica, in the state of hard rock crystal, is a better conductor than bismuth or lead, but if the crystal be reduced to powder, the propagation of heat is exceedingly slow. Through transparent rock-salt, heat is copiously conducted, but through common table salt very feebly. Asbestos, he explains, is composed of certain silicates in a fibrous condition ; and he could place some asbestos in his hand, and in it a red hot iron ball, which he could hold without inconvenience. That the division of the substance should interfere with the transmission might be reasonably inferred, for heat being motion, anything which disturbs the continuity of the molecular chain, along which the motion is conveyed, must affect the transmission. In the case of asbestos, the fibres are separated from each other by spaces of air ; the motion has, therefore, to pass from solid to air, and from air to solid, and it is easy, consequently, to see that the transmission of vibratory motion through this composite texture must be very imperfect.*

* Tyndall on "Heat."

Another of the Chalmers-Spence moulds is a patent ingot block for soldering, melting, and moulding ingots; this is provided with a basin and mould, and the metal being placed in the mould and covered with a piece of charcoal to confine the heat, is quickly melted. An asbestos lid is held over the block and the melted metal allowed to run from the channel into the mould where the ingot is formed.

There are many other blocks of various descriptions manufactured by them, all of an exceedingly useful character; the patent ring block, for instance, for soldering stone set rings, is manufactured in cup form containing an asbestos paste. The ring being partially buried, with its

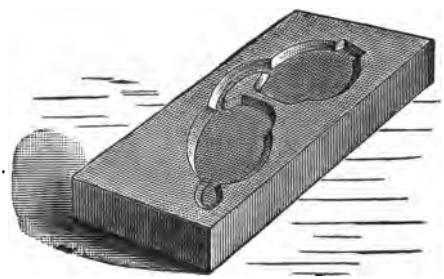
Patent Ring-block for Soldering Stone-set Rings.
(The Chalmers-Spence Company.)

stone embedded in the paste, an asbestos braid is passed through the ring as a shield, and the exposed portion can then be soldered without the slightest danger of injury to the stone. Spectacle and eye-glass blocks as shown on opposite page are formed for use in much the same way, so as to be of great assistance to the makers of these things.

A kind of tapestry is manufactured in France out of pulverized asbestos. The asbestos is reduced to powder in such a way as to preserve the short fibres, which are bound together by means of a cement. This product, which is about one-half asbestos, is stretched over a wire gauze, and when finished will take a fine polish. Woodwork covered by this material is thus rendered fireproof, and can be used for the interior lining of safes or wooden cupboards containing deeds or other

articles necessary to be preserved. Chloride of zinc, which is used in the manufacture of a certain class of incombustible cloths, is volatile at a high temperature, and its vapours then become so dangerous that it is impossible to enter a room the woodwork of which has been protected by this salt, when exposed to a temperature at which ordinary wood will take fire.

Asbestos is also used in America in the manufacture of fire-side rugs, which are woven in plain colours for after decoration.



Spectacle-block. (The Chalmers-Spence Company,)

The foregoing comprise some only of the very numerous and diverse applications of asbestos which might be referred to or described; and this part of the subject must necessarily be far from complete; indeed, it would be impossible to make it so, without adding to it day by day as the constantly increasing items of special usefulness are brought forward. The writer trusts, however, that the matters described are sufficient not only to indicate the almost universal use of this singular mineral, but to confirm the statement with which he started, that asbestos is one of Nature's most marvellous productions.

CHAPTER XI.

SUBSTITUTES AND SIMILARITIES.

SLAG WOOL—Origin of—Pele's Hair—Properties of Slag Wool—Defects—Rock Wool—Patent Fire and Sound Proof Plastering—Infusorial-earth or Fossil-meal—Woodite—Whaleite—Wood Wool.

AMONG the numerous materials and compounds put forward as substitutes for asbestos, slag wool possesses very high qualifications as a non-conductor and a fire resister; it is applicable to many similar uses, and as to some of the purposes to which it is applied, it presents by no means insignificant qualities as a competitor.

Its history is singular. That curious natural production of the lava beds of Hawaii, called by the natives Pele's hair, (Pele being the name of the goddess who is supposed to dwell in the crater of Kilauea), doubtless originally suggested the manufacture.

Pele's hair is a basic glass, a filamentary variety of obsidian, containing long cylindrical cavities. Its production is brought about by gusts of wind crossing the viscid lava at the moment of its projection into the air by the steam escaping from the surface of the lava lake, its action in this way forming a kind of natural spun glass.* Miss Gordon Cumming † describes it as a silky volcanic hair, comparing it to the byssus of certain shells, and says that handfuls of it can occasionally be collected from the rocks to which it has drifted, most of it having a sort

* "Some very fine glutinous lavas are drawn out into fine filaments as portions are tossed into the air by the escaping steam."—Geikie, "Geol."

† "Fire Fountains of Hawaii."

of pear-shaped drop attached to one end. It is brittle to handle, yet the birds collect it for lining their nests. Its composition, which is as follows, will sufficiently account for the brittleness :—

Silica	51·19
Magnesia	18·16
Peroxide of iron	30·26
	99·61

The formation of this volcanic hair was very carefully watched by Professor Dana, the celebrated American geologist, who was one of the scientific party sent out by the United States Government in 1836-42, as a Government Exploring Expedition, and he has given the following interesting account of the process, as it was carried out under his eyes.*

At one of the pools of the crater by which he stood, the formation of this capillary volcanic glass was going on; and, as it was carried away by the wind, it thickly covered the surface of the rocks to leeward, where it lay like mown grass, its threads lying parallel, and pointing away from the pool. It soon became apparent, as he watched the operation, that it proceeded from jets of liquid lava, thrown up by the process of boiling. The currents of air blowing across these jets, bore off small points and drew out a glassy fibre, such as is produced in the common mode of working glass. This delicate fibre floated on till the heavier end brought it down, and then the wind carried over the lighter capillary extremity. Each fibre was usually ballasted with the small knob which was borne off from the lava jet by the wind. Mark Twain, who witnessed the scene by night, says that through their glasses the little fountains scattered about looked very beautiful. "They boiled and coughed and spluttered, and discharged sprays of stringy red fire, of about the consistency of mush, from ten to fifteen feet in the air, along with a shower of brilliant white

* "U.S. Geological Exploring Expedition," 179.

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sparks—a quaint and unnatural mingling of gouts of blood and snowflakes."*

The scoria from which the fibre is made, or rather the lava that would have constituted scoria, had it cooled upon a floating stream, is mostly glassy in texture, a kind of ferruginous basaltic obsidian, the result of rapid cooling. This scoria has the following composition :—

Silica	50·00
Protoxide of iron	28·72
Lime	7·40
Alumina	6·16
Potash	6·00
Soda	2·00
	100·28

Professor Dana's description was very suggestive, but the time was not yet ripe for any practical result. A year or two passed on, and then Percy, the metallurgist, whilst on a visit to Dowlais, was struck by the formation of a hair-like form of slag, bearing a strongly marked semblance to Pele's hair, which he thus describes.† A little slag was seen to be leaking out through the clay-stopping, which was placed round one of the twyers at the back of the hot-blast furnace, and as it was in the act of escaping it was caught by the regurgitating blast, and blown out into fine threads, intermingled with minute adherent globules of glassy slag, which so exactly resembles Pele's hair that one cannot be distinguished from the other.

The mode of manufacture of this slag fibre, and its usefulness for a variety of purposes, was now very quickly seen; it was not to be supposed that the method of production having once been pointed out, it would long remain without some attempt at utilization. The form was singularly suggestive, especially when the composition of the slags produced in metallurgical operations is considered; these being essentially

* "The Innocents at Home."

† Percy on "Metallurgy," art., "Slags."

compounds of silica with earths, chiefly lime, magnesia and alumina, or with metallic oxides, such as protoxides of iron or manganese;* the three principal constituents being silica, lime, and alumina, the silica being the acid which neutralises the other two bases.

The way was now clear for the introduction of a new material to compete with asbestos which, although rapidly growing in favour, especially for engineering purposes, was dear. The brittleness and glassy texture of the slag fibre was certainly against it, as were also the small metallic pellicles, which it was found could not be entirely eliminated; still, if birds could utilize it for lining their nests, it was manifest that there were many useful purposes to which it could be applied; and these have, on continued experience of its qualities, so multiplied, that the material is now in considerable demand.

Attention was early directed to this substance by Mr. Charles Wood, of Middlesbrough, in a paper read by him before the Society of Arts, some time back, and to whom we are indebted for so many improved methods of dealing with slag that he is termed by Mr. Gilbert Redgrave "the pioneer of slag utilization."

Commonly spoken of as "slag-wool," this refuse production of the blast-furnace, which has hitherto so detrimentally encumbered the ground, and disfigured the country round about all the seats of the iron industry, offers a notable example of the utilization of waste products. If we take Mr. Redgrave's estimate of the annual production of cast iron in the United Kingdom alone at 13,600,000 tons, and the weight of the refuse slag at 1¾ tons per ton of pig iron, it will be seen that the vast heaps of this refuse by-product are increasing at the rate of upwards of 18,000,000 tons annually. This enormous mass of refuse, therefore, encumbers the ground to such an extent that, irrespective of any profit to be derived from its utilization, it is manifest what enormous advantages would be gained by its dispersion.

* "The Useful Metals and their Alloys," Pickett, 623.

In America slag wool, which is there termed "mineral wool," is manufactured by the "Western Mineral Wool Company," of Cleveland, in the State of Ohio. In England it goes by the name of "silicate cotton," and although the use of it here does not progress in anything like an equal ratio with its advance in estimation in the States, it is manufactured on a considerable scale at Middlesbrough for Messrs. Frederick Jones & Co., of Kentish Town, and their agents, Messrs. D. Anderson & Co., of Bow.

The process of manufacture consists in subjecting a small stream of molten slag to the impelling force of a jet of steam or compressed air, which divides it into innumerable small spherules, forming a spray of spark-like objects; the slag being dispersed, or broken up, by the jet of steam into countless small bead-like particles, each of which, as it is blown away, carries behind it a thread of finely drawn-out slag in extremely delicate filaments. This process is aptly compared by Mr. Redgrave to that of the production of the threads which are drawn out from sealing-wax when the latter is hastily withdrawn from the paper. These fine threads are sometimes two or three feet in length, and occasionally much longer; these readily break up into much smaller ones, which, in bulk, look like a mass of cotton of a somewhat dingy white colour, the length and fineness of the threads being dependent upon the fluidity and composition of the material under treatment. When the slag is of the proper consistency the shot are small at the outset, and to some extent are absorbed into the fibre; but in no case will they entirely disappear; it accordingly becomes necessary either to separate the two by strong currents while still in mid-air, or else to put the bulk through a riddling machine. The finer and lighter threads are carried away from the shot, the heavier fibres making a gradual separation between the extreme fine and the coarse. In order to collect the fibres and separate them from the beads, or heavier portion of the slag, the jet is now arranged at the open mouth of a cylinder of sheet iron, in which a strong air current is induced by means of additional jets of steam. This tube or shaft is furnished with

a shield or striking plate, which detains the heavier particles, the lighter slag wool being carried by the draught upwards and onwards into a large chamber, constructed like a gigantic meat safe, having its walls formed of wire netting with about sixteen meshes to the square inch. Here the steam condenses and escapes, and the slag wool, which may be aptly compared to flakes of snow, is deposited on the floor and round the sides, the lighter portions being carried to the greater distances, some flakes even attaching themselves to the ironwork of the roof. The filaments of slag formed in this way, though of considerable length, are of such delicacy and fineness that they are broken up into numberless fragments and felted together into a substance much resembling cotton wool.*

The product of the blast is divided into two classes:—

The Ordinary, which includes all the fibre weighing over 14 lbs. and less than 24 lbs. to the foot cube; and

The Extraordinary, which comprises all that comes under 14 lbs. to the foot cube.

Mr. Charles Wood found the product to possess the following valuable qualities:—

1. Extreme lightness and absolute fire-proofness (to which the American manufacturers add that it is also frost-proof, vermin-proof, sound-proof, indestructible, and odourless).

2. Marvellous powers as a non-conductor of heat and sound.

3. So great an amount of porosity that it will absorb large quantities of water, and readily retain it for a considerable time.

Although the resemblance of this material, so far as its outward appearance is concerned, to wool and cotton is so close as to have given rise to the names mineral wool and silicate cotton, by which it is known in America and England respectively, yet this is as far as the comparison can be followed. The hollow-jointed structure of the organic fibre, which gives it its flexibility and spinning and felting qualities, is altogether wanting in slag wool; which, as already shown, is simply spun-glass of irregular thickness, without elasticity or any such

* See Mr. Gilbert Redgrave's description, *Jour. Soc. Arts*, No. 1,941.

features as the imbrications or spicules of wool or cotton necessary for facilitating the weaving process. There are, indeed, certain rough surfaces and markings on the fibre incident to its make, but these are only visible under a strong lens. The drawing out of the fibres is a purely mechanical operation, and is a remarkable illustration of some of the various forms mineral substances will assume under different conditions of cooling.

One cubic foot of slag will weigh 192 lbs., and the same weight of ordinary mineral wool measures 8 cubic feet; the wool fibres, therefore, encase eight times the quantity of air which is contained in the slag. In other words, the cubic foot before conversion contains 100 per cent. of material and after conversion only 12 per cent.; the product consequently contains 88 per cent. of its volume of air. The extra grade has 92 per cent. of its volume of air, and is consequently much superior to the ordinary as a non-conductor; but even in the finest product there is a great dissimilarity in the shape and thickness of the fibres. Slag wool, therefore, consists essentially of fine interlocking mineral fibres forming a mass of minute air-cells which give it its property of a non-conductor; air, when unconfined, being so subtle and rapid in movement, and so slow to convey heat, except by its own motion, that mineral wool forms a good distributor of heat, and at the same time presents the greatest barrier to its transmission, according to whether it has or has not freedom to circulate. If the air-confining substance is not very loose and porous it will be found to transmit heat, and the reduction of the percentage of volume of air, by making the material more compact, develops its capacity for conducting heat.

As illustrating this view, the following tables have been published by the Western Mineral Wool Company, which are worth quoting here for several reasons applicable to the subject. No. 1 was prepared by Mr. J. J. Coleman, and was read by him before the Philadelphia Society of Glasgow, and No. 2 was compiled in order to show the non-conducting properties of different materials at even thickness:—

No. 1. Relative heat-conducting power of various materials used as boiler coverings :—

Mineral wool	100
Hair felt	117
Cotton wool	122
Sheep's wool	136
Infusorial earth	136
Charcoal	140
Sawdust	163
Gasworks breeze	230
Wood and air space	280

No. 2. Non-conducting property of various materials at even thickness :—

Black slate	100
Sandstone	71-95
Fire brick	61-70
Asphaltum and soft chalk	45-56
Oak, pine, and wood and plaster	25-66
Sulphate of lime and sand	18-70
Sawdust and tan bark	17-20
Asbestos cemented	18-20
Fine asbestos in thread	13-15
Extra mineral wool, ordinary mineral wool, raw silk	8-13
Ice	0

Among the many comparative tests that have been from time to time made with the view of determining the most efficient covering for boilers, steam pipes, &c., the following may be instanced as authentic and suggestive :—

At the Paris Exhibition, 1878, some experiments were made to determine the relative value of different kinds of pipe-covering materials. The experiments were made by MM. Geneste, Herscher & Co., with twelve vertical steam pipes, all of the same dimensions, and charged simultaneously from one boiler, so that the action of the steam was precisely the same in each case. Some of the tubes were bare, and the others were covered with different non-conducting materials. The following are some of the results arrived at, as published in the "*Moniteur des Fils et Tissus*" :—

Description of the covering, or the state of the surface of the pipes.	Thickness of covering.	Pressure of steam absolute.	Temperature of the air around the pipes.	Quantity of water condensed per hour per sq. ft.
	Inches.	lbs.		lbs.
Pipe of polished brass (bare) .	—	54	77·9	0·50
Pipe of galvanised iron (bare) .	—	54	78·2	0·81
Covered with plaited straw .	2·00	54	76·7	0·37
Composition A . . .	1·58	54	77·0	0·41
Composition B . . .	1·58	54	77·3	0·41
Composition C . . .	1·58	54	77·3	0·54
Asbestos	1·38	54	76·0	0·37
Asbestos	3·15	54	77·9	0·31
Silicate cotton	2·36	54	76·7	0·27
Wood	0·71	54	76·7	0·35
Felt	2 thicknesses	54	76·8	0·37

The materials, A, B, and C, representing three approved boiler cement or non-conducting compositions, ranked last, showing a result very little better than that of a bare tube, polished. Taking into consideration its incombustible and indestructible properties, the silicate cotton proved to be by far the most preferable substance as a non-conductor; whilst its cost is much less than asbestos.*

A wrought-iron tank 6 feet in diameter and 12 feet high, containing steam under 35 lbs. pressure, condensed 146 lbs. of steam per hour. Now 146 lbs. of steam represent, at the rate of $7\frac{1}{2}$ lbs. to 1 lb. of coal, the combustion of $19\frac{3}{4}$ lbs. of coal per hour, or 460 lbs. per day of twenty-four hours. Allowing \$3.00 per ton for coal $460 \div 2000 \times 300 = 69$, which is the loss in cents per day from condensation; in a year of 309 days the loss would be \$213.21; the exposed surface of the tank was 225 square feet. Figuring from this data, together with the known value of mineral wool, it may be stated that at a cost of 15 cents per square foot, or \$33.75 for the whole job, this tank can be so protected by a covering of mineral wool that the loss will only be 10 per cent. of the above, or, say, \$21.32 per year.†

* *The Engineer*, March 12th, 1880.

† *The American Engineer*, November 19th, 1885.

For ordinary fireproofing purposes the slag wool is enclosed between two thicknesses of galvanized wire netting, which netting is kept at proper distance apart by loops of wire passing from front to back, and the layer of slag wool of a suitable thickness (an inch has been found sufficient for any purpose) is compactly felted between these two sheets of netting. Prepared in this way, very tough, light, and flexible sheets of "silicate cotton wire-net felting" are obtained. It has been found that in the thickness of an inch one ton of slag wool will cover 1,800 square feet, say 1¼ lb. to the square foot. It is employed, therefore, in this form under joists, instead of pugging, as a lining for corrugated iron buildings, sheds, &c., and for many other structural purposes.

As a non-radiator of heat and cold, it appears to be well adapted as a lining for temporary buildings either in extremely hot or very cold climates. It can also be advantageously employed as a lining for refrigerating chambers. In 1885 Mr. T. B. Lightfoot, C.E., tested it thus:—Two blocks of ice, weighing 30 lbs. each, were placed in separate boxes, one of them being surrounded by two inches of slag wool and the other with six inches of charcoal. Three days afterwards these boxes were opened and the unmelted ice weighed: the ice block in the box surrounded by slag wool was then found to weigh 13 lbs., and the other 5½ lbs. only; showing that two inches of slag wool form a better non-conducting lining than six inches of charcoal.

As an insulator it takes high rank. It is said to be liable to become pulverized, if used on board ship, on account of the incessant vibration and the motion of the vessel at sea. Yet it does not seem to be so objectionable on locomotives, although the vibration in that case is necessarily severe. It has been used for many years by the Chicago, Milwaukee, and St. Paul Railway Company for jacketing locomotives, and the passenger cars of the Pennsylvanian Railway are lined with it.*

It also forms a good filling material, where the object is to

* *Canadian Mining Review*, vol. i., no. 4.

prevent the transmission of sound, on account of the vast number of minute air-cells distributed through it.

The result of practical experiments with slag wool, packed round joists, or employed in a loose state as a backing for fire grates, shows that the heating power of a fire is greatly enhanced by compelling the radiation from a stove to take an outward direction, and the combustion of the fuel is so thorough when a grate is packed all round with it, that, as soon as the fire gets under weigh, little or no smoke will rise, and, even

English make. ½-inch objective.

after burning all day, if the fire be allowed to go out gradually, the residuum of ash will be surprisingly small.

It is now used largely for covering boilers, steam and water pipes. For boiler and pipe coverings slag wool mainly relies, in its competition with asbestos, on its comparative cheapness, and, as asserted by the manufacturers, on the fact of its being a better non-conductor. But, however that may be, its most manifest inferiority in this respect lies in its want of elasticity and lubricity. Even when most carefully prepared it has a harsh, gritty, metlliac feel, when crushed between the fingers,

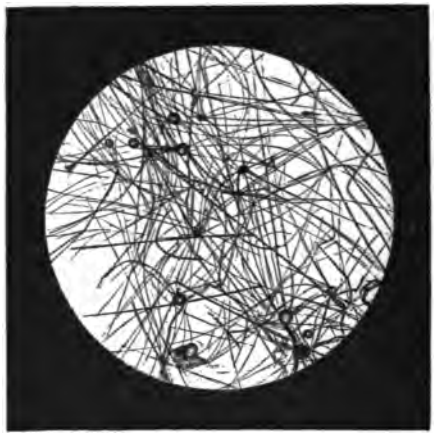
altogether unlike the soft silkiness and unctuosity of asbestos. The cause of this is at once apparent even on examination with the naked eye, but, when placed under the lens, its sharp, acicular fibres, studded with minute metallic grains or pellicles, are brought out into strong relief, these last being globules or pear-shaped drops of basic glass, precisely such as are seen in Pele's hair, being the points first blown off from the liquid slag. In the two first diagrams these pellicles are exaggerated in size, by manipulation of the fibre, so as to bring out clearly their peculiar form.

American make. ½-inch objective.

From the peculiar formation of the material as it comes from the factory, it is very difficult to obtain a satisfactory micro-photograph of it; the fibres are so crushed and closely compacted that it is not practicable to draw out a clear fibre, as can be done with some amount of care with asbestos: but the two following diagrams will give a general idea of the construction.

In regard to these, Mr. Eady, who kindly furnished the photos, says, as to No. 1, "the brittle, glassy filaments in this are exceedingly fine, and the bulbs are both small in size and

few in number. Owing to the transparency of the filaments this was difficult to photograph; its extreme fineness can be best judged by comparing this with the equally magnified sample of American make"; respecting which last he says, "the irregular character of the glassy fibre shows the artificial nature of the wool; the filaments are much coarser and the bulbous ends larger." It is quite possible, however, that an injustice has been inadvertently done to the American make by difference of sample, that of No. 1 being a fine, picked



No. 1.—Silicate Cotton. Manufactured by Frederick Jones & Co., Kentish Town.

specimen, and No. 2 being the ordinary first quality sample, sent over from the works at Cleveland.

Another very important property of slag wool is its power of absorption, which makes it capable of holding water to the extent of its own volume. Thus, when water is pumped into a burning building, instead of running through into the street and being wasted, as in the case of an ordinary iron and con-

crete construction, the water is held by the slag wool, as in a vast sponge, and will, owing to the surrounding heat, evolve sufficient steam to extinguish the flames, or at any rate to powerfully assist in so doing.

Being vermin-proof it is additionally valuable as a lining for wainscots, passages, pantries, dining-rooms, and ceilings; its glass-like fibres causing great irritation to rats and other vermin, as well as insect pests coming in contact with it.

It is also said to be an antiseptic, and this property, taken in conjunction with its great porosity, adapts it to some medical

No. 2.—Mineral Wool. Manufactured by the Western Mineral Wool Company, Cleveland, Ohio.

purposes; for cholera belts, for use in hot climates, chest protectors, &c. Moreover, these antiseptic qualities can be specially utilized in the construction of hospitals, infirmaries, &c.

There are many other uses which might be enumerated, all tending to show the value of slag wool for certain purposes, and the many points in which it can compete with asbestos.

Its main feature is, of course, its comparative cheapness; but it is to be remarked that there is scarcely one point of value cited which does not carry with it a corresponding disadvantage. For instance, when its vermin-proof character is mentioned, the warnings of Percy and Bloxam at once occur to the mind. The former* specially cautions his readers that these slag fibres have to be handled with care, because the fine short threads, being very brittle, easily penetrate the skin and cause irritation; and Bloxam says, the fine filaments, being so exceedingly brittle, and the material itself so light, the needle-like particles are liable to become diffused in the air of a room, and pass into the lungs and eyes, and so become the source of serious mischief.†

Again, its power of absorbing water is doubtless a valuable quality in case of fire, but it has one corresponding disadvantage, as a boiler and pipe coverer, inasmuch as if a leak should occur, or exterior damp penetrate it, it at once becomes the cause of corrosion. Although water is the primary cause of rusting, the percentage of sulphur contained in the slag becomes dissolved in the water, and, in the form of sulphuric acid, will attack the surfaces, unless they are kept dry by radiated heat. This defect, however, is now in some measure overcome by entirely manufacturing the article from non-sulphur-bearing rocks, so as to render it absolutely free from sulphur and its compounds. It is then called *rock wool*, and although more costly than slag wool, the difference in weight reduces the cost of transport in favour of the former.

Practically the main objections to its use are its glass-like texture and the grittiness caused by the minute pellicles, which cannot be entirely eliminated, together with its liability to pulverise under vibration, and its water retention.

In its normal condition a cubic foot weighs 12 lbs., and its cost, as applied to steam-pipes, is 2d. per square foot for each inch in thickness.

The Patent Fire and Sound Proof Plasterings (Mr. W.

* Percy on "Metallurgy"; art., "Slags."

† Bloxam on "Metals."

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COTTAGE RESIDENCE

Designed by Messrs. Frederick Jones & Co., of Kentish Town, showing walls, ceilings, roof, and flooring protected by Silicate Cotton.

Hitchins' patents), recently purchased by Messrs. F. Jones & Co., made in many ingenious ways with a backing of silicate cotton, have proved their value repeatedly. The same manufacturers furnish a variety of fibrous wire netting, and fibre-ligneous slabs and compounds, which are rapidly making their way in the estimation of architects and builders, and all others who are desirous (as who are not ?) of ensuring perfect immunity in their habitations from damp, for preventing the transmission of sound, and the spread of fire in the case of conflagration. In this plastering, no lathing, lime or hair is required; there is no annoyance from dirt or rubbish, and the walls and ceilings can be painted or decorated the same day that they are put up. Cornices and enrichments, prepared in long lengths, are fixed dry, and buildings thus treated are rendered fit for habitation or decoration at once. The same firm's Salamander compound is composed of silicate cotton and prepared plaster, and when set this is not only a fire-proof non-conductor, but it possesses sufficient elasticity to prevent cracking under even extreme heat.

The illustration on opposite page represents a cottage residence specially designed by Messrs. Frederick Jones & Co., to illustrate their method of isolating such a structure, with a view to rendering it at the same time fire, frost, sound, and vermin proof, perfectly cool in summer and comparatively warm in winter. The ceilings and walls can be fitted with Hitchins' patent fire- and sound-proof plaister slabs, which have a lining of slag wool between the plaister and the wall or ceiling. These slabs are made specially to suit the building; they can be of any size and ornamented in any way desired, either by moulding, painting, or gilding; they can be fitted with the greatest ease and simplicity and without dirt or mess of any kind.

The cut on next page shows one of the same firm's patent portable anti-thermal and anti-septic huts, which they claim to be impervious to external climatic influences and to be so constructed that it can be readily put together or taken to pieces by any ordinary workman in a couple of

hours. As these huts are not only fire, heat, frost, and sound proof, but give absolute freedom from insect pests, they are undoubtedly a great step in advance. Soldiers' huts, gentlemen's fishing boxes, and other buildings of a similar or temporary character can be fitted in a precisely similar way if constructed of wood or any other material. Apparently this would be a great boon to troops in camp, who, in such huts as these, would enjoy complete immunity from the annoyances caused by the all too friendly disposition of the insect inhabitants of the present huts, whilst they could at the same time depend on a tolerably equable temperature, cooler in summer

Portable Anti-thermal and Anti-septic Hut. (Frederick Jones & Co.)

and warmer in winter than that offered by any other system at present devised for ordinary camp-dwellings. In the wooden houses of Canada and Norway it is a common practice to ram in sawdust between the outer timbers and the match-board lining; and although this makes the house undoubtedly warm, it forms a delightful harbourage and breeding ground for all insect pests. In Russia, where things in this respect are much worse, but much less regarded, it is almost needless to say that the Government has at once adopted the idea, and it is anticipated that a large order will be at once given for these portable huts for housing the troops in camp.

Soapstone.—This soft magnesian mineral frequently occurs in association with serpentine, and possesses many of the valuable properties of asbestos. Mainly composed of two of the most durable substances known for exposure to fire or atmospheric influences, it is often used in competition with asbestos, or enlisted as a valuable auxiliary, in certain forms of manufacture.

Technically called Steatite (Ger., Speckstein), it is also occasionally termed Synophite, as being an associate of ophite. The word *Steatitis* is used by Pliny as the name of a stone resembling fat. Like asbestos, soapstone is a hydrated silicate of magnesia, a more or less pure and compact talc, generally of a grey or greyish-green colour; it occurs in massive form, crystalline, granular, or impalpable, and is very greasy to the touch. Sometimes it is found in a fine granular, or cryptocrystalline form, of a milk-white colour and pearly lustre, soft enough to be used as chalk (craie de Briançon); it is then called Venetian or French chalk, and is the substance used by tailors and others for marking cloth and removing grease and other stains.

Analyses of two samples give the following:—

Silica	62·8	63·49
Magnesia	33·5	31·75
Water	3·7	4·76
	100·00	100.00

A little iron is occasionally found replacing magnesia. Sometimes it appears as a pseudomorph, taking the form of apatite at St. Just, Cornwall; or of arragonite in Bohemia.

Lapis ollaris (potstone, Ger., Topfstein) is an impure steatite of a greyish-green colour and slaty structure.

Soapstone occurs abundantly in many parts of the world. In the United States and in Canada it can be had in large quantities, and sometimes of remarkably pure quality. Large deposits have been found in several districts in California. In Arkansas a fine quality occurs in Saline County, where it is

worked by the Arkansas Soapstone Manufacturing Company. The deposits here are mixed up in an unusual way with slates and serpentine, but are very pure, averaging 62 per cent. of silica and 34 magnesia.

In the Eastern Townships of Quebec it is abundant: the quality is not always good, but a good deal can be had in a comparatively pure state. Deposits exist at East Broughton, Lake Nicolet, Hatley, Potton, and Wolfestown. At the last-named place it is found in a bed from one to two feet thick in black and grey talcose schist; this is mostly pure and occasionally translucent. Excepting at Wolfestown, where a factory has been established for working it, and where slabs of a fine quality can be had, not much use is made of it in Canada. Possibly the high prices now realized for asbestos will cause greater attention to be given to the valuable properties of this refractory mineral.

In England, a company, operating at Newcastle-on-Tyne, imports it in bulk from China, mostly for use in the manufacture of pigments; the peculiarity of the Chinese soapstone consisting in the large proportion of potash it contains, amounting occasionally to as much as 60 per cent.

The following are some of its most important properties, which serve to explain the estimation in which it is held for manufacturing purposes. It is not liable to corrosion, is without expansion or contraction, and is unaffected by moisture, atmospheric influences, or chemical fumes. It will not discolour with age, and is a better radiator than any metal. When pure, and of a hard nature, it may be sawn into slabs, or made into knife-edged bricks, and, being a non-absorbent, may be washed without injurious effect. It can be used for almost any ornamental purpose, offering a fine surface for painting with oil or water colours; will take the richest tint, and when retaining its own, exhibiting a pure transparent white. Its refractory nature adapts it for use as firestones, and as a lining for furnaces and fireplaces, especially those designed for anthracite, as well as for the manufacture of crucibles. When highly heated it loses the small proportion of contained water, and

then, becoming much harder, assumes a dark green colour, and is susceptible of a fine polish; in this state it is used by the Chinese for the manufacture of images, especially of their household gods: hence its name of figure-stone. The minerals pagodite and lardite * also are simply soapstone.

Possessing unusual powers of withstanding atmospheric and chemical influences, it has long been used, in China and Japan, as a preserving medium for woodwork, and buildings or monuments erected with any stone liable to disintegration.

In the manufacture of pigments it is simply invaluable. When it is remembered that one of the main causes affecting the durability of iron bridges, and metallic structures generally, is the tendency to oxidation, arising from the humidity of the atmosphere, it will be at once understood that if proper precautions were not taken to obviate this element of danger, by finding some means of lessening the corrosion constantly taking place, very serious results might ensue. And this liability to corrosion is still more persistent in ships both of iron and steel, in the latter especially, because of the difficulty of finding some kind of pigment capable of taking a firm hold of the fine fibres of the steel plates. Many modes of overcoming this difficulty, such as rough-rolling the steel, have from time to time been tried, and experiments are constantly being made in this direction, but these have mostly been without successful result. Some time ago, Mr. Goodall, Surveyor of Shipping to the Trinity House, spent a considerable time in the endeavour to find some material possessed of the necessary power of taking hold of the fine fibres of steel, and in the end gave the result of his experiments to the public. In doing this he strongly urged on paint manufacturers the desirability of trying soapstone as an ingredient in any paint designed to be employed in the protection of iron and steel ships, especially in the coal bunkers, as he had found nothing so suitable for accomplishing this object. The chief difficulty met with in carry-

* "C'est à la steatite que doivent être rapportées une partie des substances pagodite, lardite, &c., avec lesquelles les chinois sculptent des figurines."—De Lapparent, 376.

ing out his ideas was that steatite when mixed as an ordinary paint, that is, with raw or boiled linseed oil, driers, turpentine, terebine, &c., the steatite forming the basis, would neither mix properly nor dry hard, and was quite useless as a protective paint; but with quick-drying varnish it was a success.

When ground into an impalpable powder, the grain of soapstone is of such extreme fineness as to be all but infinitesimal, and this quality, coupled with its imperishability, endows it with extraordinary qualities. It is, moreover, lighter than any metallic pigment, is not liable to be thrown off by vibration, and will cover a much larger surface than zinc white, red lead, or oxide of iron; all of which, especially the latter, are very difficult to obtain free from adulteration. The red oxide of iron being the pigment generally in use for iron structures can, according to Professor Lewes, be easily tested for soluble sulphates, by warming a little of it with pure water, filtering, and then adding to the clear solution a few drops of pure hydrochloric acid, with a little chloride of barium solution. If a white sediment is then formed in the solution, the sample should be at once rejected.

Oxide paints mixed with boiled oil are now regarded as failures; naphtha is a far better combination, corrosion resulting from the oxygen contained in the oil.

When soapstone, reduced to a fine impalpable powder, is mixed with a quick-drying, hard-setting varnish, it furnishes a paint superior to asbestos, not only of great covering capacity and firmness, but of an even, enamel-like surface. When ground by itself pure soapstone is transparent, the added colour alone therefore, is shown in the pigment. Its remarkable smoothness is due to the extreme minuteness of the atoms of which it is composed, and to which it may be reduced. Its extraordinary fineness and adhesive nature is shown by the fact that you may write with it on plate glass, the steatite finding a ready hold on its highly-polished surface. It consequently finds perfect and permanent adhesion to the surface of the smoothest steel.

The causes of rusting in ships are contact with sea water and the various acids it may contain, atmospheric influences, or electric or galvanic actions. The first two can be cured by preventing the sea water and the atmosphere from coming into contact with the steel, but in order to do this it is necessary to have a paint which will adhere to the fibre of the steel, which will be perfectly air and water tight, and which will have sufficient elasticity not to crack with the vibration of the vessel or the slight contraction and expansion of the steel. This elasticity, Mr. Goodall says, may be obtained in steatite by using a suitable varnish to convey it to the steel in the form of paint, which varnish should contain evaporating spirits, combined with a certain proportion of slow-drying oils, in order that the paint may dry and at the same time keep its elasticity. Varnish alone is porous, and admits the atmosphere and moisture to the body coated with it, but when mixed with steatite, owing to the minute atoms of which that mineral is composed, the fine pores are completely closed, and the paint becomes air and water tight. The third cause of rusting is due to electric or galvanic actions. The gums of which varnishes are made are, like steatite, isolators of electricity or galvanism; consequently, if a vessel's iron or steel plates inside and out, together with all iron or steel attached thereto, are properly coated with steatite paint they are completely isolated, and unable to set up electricity or galvanism from the atmosphere, sea water, &c., as they certainly will do if coated with paint made from metallic pigments.*

Infusorial-earth or Fossil-meal is also now much brought into use, either as a composition in conjunction with asbestos, or in competition with it. It is a siliceous mealy earth, composed of the flinty shields or skeletons of infusorial animalculæ; the infusoria found in the mineral called tripoli and in bog iron ore being mostly of vegetable origin.

Fossil-meal is a white, greyish white, or brown chalk-like earth, which occurs in deposits, often many miles in extent,

* *Invention*, May 10, 1890.

and either uncompacted as a fine earth, or compacted and moderately hard. The infusoria of which it is composed abound in moist earth, in which they have been found alive at 60 feet below the surface, in both fresh and salt water, often covering leagues of the ocean and giving a beautiful tinge to it from their vivid hue, from the mud of which they have been brought up from a depth of 1,600 feet; and occasionally under peat. The infusorial beds of Virginia, a vast accumulation of these microscopic organisms, are of tertiary age. In some parts of northern Germany deposits occur of more than 60 feet thick; the minute organised specks of matter requiring the aid of a microscope even to discover the fact of their existence, many of them being less than the three-thousandth part of an inch in length, of which it would require thirty-five thousand millions to fill the space of a cubic inch.

Near the mouths of the great rivers which flow into the Baltic Sea large banks, islands, and very broad tracts on the coast are known to be derived from this source. They are discovered in all climes, and have been found in almost infinite abundance in flint and opal, in the latter of which they encase the solid and translucent interior.

The composition of this fossil earth was first made known by Ehrenberg, who discovered 100 different species of diatoms in the beds of Richmond, U.S.A.

A large manufactory is carried on by the company owning the United Kieselguhr mines at Chelle, who claim to be the largest producers of the meal; the English agent is Mr. F. E. Clotten, of 23, Leadenhall Street, London.

The non-conducting qualities of the meal indicate its usefulness for the coverings of boilers and steam pipes, for the isolation of engine rooms, for protection against heat and cold, for refrigerating rooms and ice manufactories, for rendering floors, walls, and ceilings fire-proof and rot-proof, as a filling material for use in the manufacture of fire-proof safes, strong rooms, and ice boxes, for the protection in transit of dangerous, explosive, or easily damaged goods, and for a variety of other purposes.

It is sold in many forms, such as pure fossil-meal, fossil-meal composition (containing a mixture of asbestos), patent removable fossil-meal plates, specially adapted for isolating engine rooms and for roofing for use in tropical climates, removable coverings, packing and boiler coverings, and for other purposes for which asbestos is generally used. As an indication of its value, as a boiler and steam-pipe covering, it is now used for that purpose on some of the vessels of the Peninsula and Oriental, White Star, Inman, and Orient lines. It is also used in the manufacture of firebricks, and as a polishing powder, and when mixed with nitroglycerine it makes dynamite.

Asbestonit is a patent compound of asbestos and some other material, manufactured by Messrs. Ladewig & Co.,* of Rathenow. It is a form of millboard recommended for packing, jointing, roofing, and many other purposes for which similar substances are available and useful. The same firm also make an asbestonit sheeting and wire-wove cloth, which is used for a great variety of purposes, including the protection of timber or wooden posts when such are required to be fixed below ground or in water.

Spun Glass.—Mr. Reed, an American citizen, has recently applied this to the insulation of copper wires for electrical purposes. The wire is first wound round with woollen or cotton yarn, twisted slackly, and this is then overlaid with longitudinal strands of spun glass; above which another strand of silk and spun glass is wound in close spiral form, over which is then placed a braid of either cotton, hemp, flax, or silk. The whole covering is then well saturated with paraffin or varnish to exclude damp.

Woodite is a patented article which takes its name from that of the patentee, and not from the substance of which it is composed. It is an elastic rubber compound, said to possess properties which enable it to compete with goods formed of rubber, gutta-percha, leather, &c., owing to its being able to resist the action of heat, oil, steam, and some acids. An asbestos and woodite packing is made to supersede the asbestos

* *Ante*, p. 179.

packing with indiarubber core, which, under high-pressure steam and heat, has a tendency to become viscous and to lose its elasticity; to obviate which the asbestos woodite packing is formed of asbestos with a woodite core. It is also put forward as a competitor with asbestos for protecting the sides of war-ships, and on precisely similar grounds, the inventor claiming that if the blocks of woodite fixed on the sides of war-vessels were to be riddled by projectiles, the only effect would be that the perforations would instantly close up again and prevent the influx of water.*

Whaleite is another form of the same material, in which whalebone cuttings are intermixed with woodite, in order to give it the rough, frictional quality requisite in waterproof mats, floor coverings, &c.

With **wood wool** we have here nothing to do, its manufacture being for sanitary purposes only. It may, however, be mentioned that a German manufacturer has recently patented a wood fibre for spinning purposes. Here the wood is first boiled in a chemical solution, as sulphurous acid or bisulphide of carbon, the fibres being afterwards dried and softened in water, and then subjected to repeated mechanical pinchings.

In addition to the foregoing there are many combinations of asbestos and rubber, and similar compounds, which are used as packings, many of them possessing good qualities of their own, to supplement the main feature of cheapness.

* *Army and Navy Gazette*, October, 1886.

CHAPTER XII.

FIBRE SPINNING.

ORGANIC AND INORGANIC FIBRES—Powers Employed—Wool—Cotton—Silk—Spider Web—Spun glass—Quartz—Chrysotile—Italian Asbestos—Delicacy and Strength of some Mineral Fibres.

THE difficulty experienced in the early attempts to spin and weave asbestos fibre was purely structural, and in order to explain this we will contrast the peculiar form of some mineral fibres with others of animal origin. These structural differences between organic and inorganic fibres can be at once perceived when such fibres are placed under a lens. For ordinary purposes of examination and comparison their distinguishing characteristics can be sufficiently well seen with a moderate power, but very high powers are sometimes employed in investigations of a scientific character. Dr. Bowman, for instance, when engaged in the examination of the structural peculiarities of wool fibres for his well-known series of lectures on the subject* occasionally employed powers as high as 8,000 diameters, or such as would magnify 64,000,000 times. A power such as this would give to a single fibre of Leicester wool the appearance of a tube 2,000 ft. long and 10 in. in diameter, the dimension of which will be better understood when it is stated that if this represented an actual metal tube, such as a gas main, for instance, its size would be sufficiently large to supply all the gas requirements for a small town.

Wool.—The first fibre selected for examination is a hair

* "Lectures on the Structure of Wool Fibres," by Dr. Bowman.

of sheep's wool, as this affords the aptest illustration of a spinning or felting fibre. In the cut this is magnified 600 diameters only, that power being amply sufficient to show its peculiar notched or serrated character, or what is technically termed its imbrications,* those irregularly shaped cylindrical scales, or plates, which form its outer structure. These overlap each other after the manner of house tiles, the effect being to give rise to very minute projections all along the surface or line of the fibre, which act like spikes or teeth, and so cause wool fibres to cling together when twisted. The imbrications thus being the cause of the felting property inherent in wool, it follows that the more numerous these imbrications are in the fibre of any particular wool, the more valuable that special variety becomes in the eyes of the manufacturer. In fine Saxon wool there are no less than 2,720 of these imbrications within the length of an inch, in Southdown there are 2,080, whilst in Leicester we find only 1,850. Thus we have no difficulty (other circumstances being identical) in assigning to each variety its relative value for manufacturing purposes. It must not be forgotten, however, that wool, being a part of the skin of the animal on which it grows, is capable of being modified to a very great extent by change of climate, food, and other surroundings, as well as by judicious breeding; but there can be no doubt that practically we now possess the best breeds of sheep possible both for wool-producing and food-producing purposes.†

Fig. 1.
Fibre of Sheep's Wool. Magnified 600 diameters.

Cotton.—In cotton the fibre becomes twisted during its growth, and although not so strong as linen or silk, its irregular surfaces adapt it for being spun into a strong yarn, from which

* Deriv.: *imber, imbris*, rain; *imbrex, imbricis*, a tile; *imbrico*, I cover with tiles.

† Dr. Bowman's "Lectures," *ubi supra*.

all cotton fabrics are made. Its peculiarity as a fibre has been thus described by Mr. Thompson: *—"The filaments of cotton are transparent glassy tubes, flattened and twisted round their own axis. A section of the filament resembles a figure of 8, the tube, originally cylindrical, having collapsed most in the middle, forming semi-tubes on each side, which give to the fibre when viewed in certain lights the appearance of a flat ribbon with a hem or border on each side. The twisted and corkscrew form of the filament of cotton distinguishes it from all other vegetable fibres." When it is important to know from what material a fabric has been constructed, it can sometimes only be discovered by the use of a microscope. It was by this means that the discovery was made that the cere-cloths in which the Egyptian mummies are wrapped were made of linen, the Peruvians using cotton alone for this purpose. Much has been said about the "parallelism" of cotton fibre in manufactured goods, but if a bit of one of the best grades of cotton cloth be examined under the lens, it will be seen that there is no such thing as parallelism among them. In a lecture on cotton fibres delivered before the Franklin Institute, Mr. Thomas Gray, jun., suggested that the usual method of determining the quality of cotton fibre, by feeling it with the fingers, was an exceedingly crude one, inasmuch as these fibres vary from $\frac{1}{600}$ of an inch in thickness for the coarsest "upland" quality, to $\frac{1}{2000}$ for the best sea island.† The finest cotton

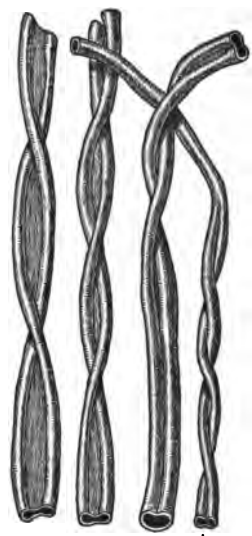


Fig. 2.
Filaments of Raw Cotton.

* James Thompson, Esq., F.R.S., on "Mummy Cloths."

† *Popular Science Monthly* (New York), vol. xxxvi., no. 4.

raised from any of the cotton-fields of the world comes from the Mississippi delta. Under the microscope this presents a beautiful structure and a perfect development; it is seen to be full of oil deposit, and has nearly 400 spirals to an inch. The form of the spiral is seen on page 213.

Fig. 3. Fibre of Raw Silk

The actual length of the fibres shown in the drawing was $\frac{1}{100}$ of an inch; the thickness of cotton fibres varies from $\frac{1}{600}$ to $\frac{1}{3600}$ of an inch. There are in an inch in length of cotton fibre from 300 to 800 twists of the cylindrical tubes.

Silk.—Then if a fibre be drawn out from the cocoon, we shall see (Fig. 3) that the construction of silk is entirely different. Whilst not of a perfect smoothness, it is in no sense imbricated or twisted spirally; consequently although the fibre of the silk-worm lends itself readily enough to the spinning process, it cannot be felted unless mixed wtih some foreign material. The fibre of silk is, in reality, nothing more than a slender rod of consolidated flexible gum, secreted from a pair of long tubes which end in a pore of the underlip of the silk-worm; which explains the peculiar appearance of the silk fibre when examined under the lens. Each thread of silk is then seen to be composed of two separate filaments. These issue from the pores, and are cemented together longitudinally by the secretion from a small gland situated near the pores, the quality of the silk being dependent on the character and difference of the two secretions. The form of the fibre, as disclosed by the microscope, shows no sign whatever of structural markings; on the contrary, it bears some resemblance to a polished metal rod, the line of junction being made perceptible by a slight grove, which gives it the appearance of two somewhat irregular lines, longitudinally attached together by the glutinous matter; each of the lines being about the two-thousandth part of an inch in diameter.

The enormous comparative tensile strength possessed by silk fibre was shown by Mr. C. V. Boys, in a paper read by him at the Royal Institution in June, 1889,* in which he states that, when the two filaments had been separated and washed they were each capable of sustaining a weight of 60 grains before breaking, and each could be safely loaded with 15 grains; the carrying power, therefore, being equivalent to from 10 to 20 tons per square inch.

Spider's Web.—Now, if we turn to the somewhat analogous case of the delicate radial thread of the common garden spider, which is of so fine a quality as frequently to be invisible to the naked eye until washed with dew or exposed by a shower, we shall be better able to understand how this great tensile strength is obtained. The filamentary secretions exist in the spider's body in a semi-fluid state, and are secreted by glands which end in four or six teat-like organs called spinnerets, minute conical projections situated near the abdomen of the insect, towards the posterior end, where, when at rest, they present a bluntly conical appearance.

Each of these is composed of a multitude of fine hair-like tubes opening at the top of the spinneret, which thus forms the spinning apparatus. The narrow space which intervenes between the basis of the anterior spinnerets is filled by a tongue-like process. The silky matter, or secretion, so long as it remains in the spider's body, is in a semi-fluid state, and issues thence by a sieve-like apparatus; each sieve, according to Bonnet, containing more than 1,000 punctured holes. When the filaments are projected from these holes they agglutinate together in such a manner that each thread is composed of from 4,000 to 6,000 fibres, but yet it is of so slender a character that, according to Leuwenhoek, it would take 4,000,000 of them to make a thread as thick as a hair from a man's beard; the thread holes being so fine and so crowded together that 1,000 of them would be covered by the point of a needle; but after the thread is woven, Meckel could not recognise it as consisting of more than 8 to 10 strands. When this silky fluid

* "Quartz Fibres," by Mr. C. V. Boys, F.R.S.

is exposed to the air it congeals rapidly, becoming of a tenacious consistence, and is then capable of being drawn out into a fine thread. This will be better understood by thrusting a piece of stick into a glue-pot and drawing it out again, when it will be seen that the adhering glue, so long as it retains sufficient heat, will remain fluid, but no sooner does it cool than it will harden, and then it can be drawn out into a fine hair-like thread, precisely as in the case of the sealing-wax referred to in the previous chapter. The single threads, therefore, with which the spinning is accomplished are in reality, each of them, composed of a multitude of strands issuing from the spinnerets and consolidated into a single fibre; so that actually the fine gossamer thread, which has become typical of the utmost tenuity, is composed of a vast number of different threads invisible to the naked eye, and even when magnified, as we see it in Fig. 4 representing only a single line.* Enormous strength in the fibre is necessary, as not only must the orb web be able to sustain the weight of the evening dews but also of summer showers, which occasionally fall heavily, and are also sometimes driven before a strong wind.

Fig. 4. Radial Thread of Garden Spider.

An interesting example of the use of the spider web by scientists is the following:—Professor Mitchell, wanting a clock to record its beat telegraphically as well as to perform in a perfect manner its work as a time-keeper, found the required makes and breaks in the battery could be effected by means of a cross of delicate wire and a mercury cup, the difficulty arising of procuring a fibre sufficiently minute and elastic to constitute the physical union between the top stem of the cross and the clock pendulum. A fine human hair was found to be too coarse and stiff, and, after many fruitless

* C. V. Boys, *ubi supra*. Wilson's "Science Jottings."

attempts, the assistance of a spider was invoked and his web, perfectly elastic and pliable, proved to be exactly what was required.*

Now, if we turn to inorganic fibres, it is well known that physicists, in their endeavour to find a really delicate torsion thread, have usually turned their attention to spun

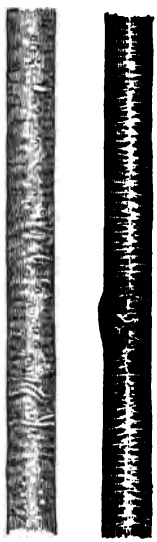


Fig. 5.
Spun Glass.

Fig. 6.
Quartz Fibre.

glass, which is about the thousandth part of an inch in diameter, and would appear to be an ideal torsion thread, its great strength enabling it to carry heavier loads than would be expected of it; but Mr. Boys confesses that he used it only to be disappointed, although apparently possessing every good quality, it is deficient in the important one of elasticity. So great had been his difficulty in finding a fine torsion thread that

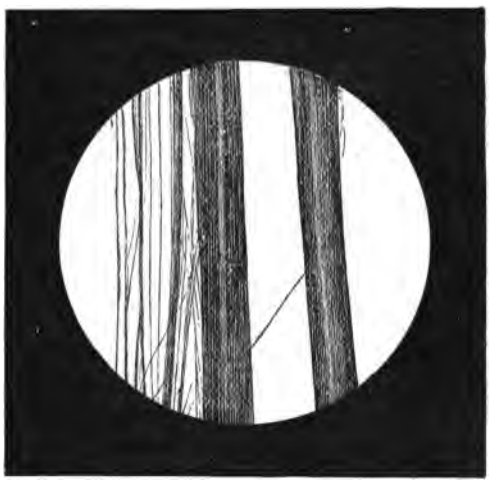
* *Popular Science Monthly*, May, 1890

the attempt had practically been given up, and in all the more exact instruments he had been compelled to use silk. The torsion of silk, however, though exceedingly small, he found to be quite sufficient to upset the working of any delicate instrument, for the simple reason that it is never constant; at one time the fibre twists in one way and at another in another, this evil effect being only capable of mitigation by using large apparatus in which strong forces are developed, the result usually being that the smallness, the length of period, and therefore delicacy, of the instruments at the physicist's disposal had, until lately, been simply limited to this behaviour of silk. When, therefore, Mr. Boys was engaged in making some improvements in an instrument for measuring radiant heat, his experiment came to a deadlock; he would not use silk and could find nothing else. Spun glass being far too coarse and a thousand times too stiff, he was driven to try by experiment to find a new material, and he explains in the paper from which we are quoting, how he managed to draw out fibres from a fine rod of quartz which had been melted and drawn out in the oxy-hydrogen jet. In this way he produced threads of great length, of almost any degree of fineness, of extraordinary uniformity, and of enormous strength. One fibre, of the five thousandth part of an inch in diameter, he had in constant use in an instrument loaded with about 30 grains. It had a section of only one-sixth of a single line of silk and was just as strong, while, not being organic, it was in no way affected by changes of moisture or temperature. The piece he used in the instrument was about 16 inches long, and had it been necessary for him, he says, to have used spun glass, which was generally considered to be the finest torsion material known, he would have required, instead of 16 inches, a piece about 1,000 feet long, and an instrument as high as the Eiffel Tower to put it in.

Turning now to the fibre of asbestos, after repeatedly subjecting some of them, especially of chrysotile, to test under high powers, which satisfied me of the nature of their structural form, I applied to my friend, Mr. Eady, of Southampton, who is experienced in micro-photography, to send me a micro-pho-

tograph of a fibre magnified in such a way as would best exhibit its structure. This he very readily did, and in those marked Nos. 1 and 2 we see a few fibres from a piece of ore, brought by myself from the Johnson Mine, highly magnified.

The first attempts were scarcely satisfactory, considerable difficulty being experienced in drawing out a couple of clean fibres entirely free from fluffiness. This would seem a very simple matter, and, judging by the naked eye, is easily accom-



No. 1.—Thetford Ore.

plished, but when under the lens, the fluffiness is quickly apparent, and a couple of clean fibres seem as hard to get as they are difficult to place in parallel lines when successfully obtained.

When this difficulty was overcome the clear, rod-like metallic nature of the fibre as seen under the lens at once explains the stubborn obstinacy with which it so long resisted all attempts to subject it to the spinning or weaving process. Under the microscope this fibre shows up as clear and distinct as a polished steel rod, and in the photograph the rounded glass-

like nature of it is distinctly seen; but, in the coarseness of wood engraving the beauty of the fibre is entirely lost, though the practical idea is conveyed. No. 1 shows the formation distinctly. In Nos. 2 and 3, although the objective is somewhat crowded and the fibre not so clearly drawn out, its composite character, and the constant rounding off, or "silking out," of still more minute filaments from what appears to the naked eye to be but a single line, is very plainly shown. Some of the fibres, on examination, seem to show long cylindrical

No. 2.—Thetford Ore.

cavities, but on closer inspection these seeming cavities are found to be merely the interstices between the minute longitudinal filaments, as will be better seen in the fibre of the Italian varieties which follow.

These fibres are of great beauty; when drawn out as finely as it is possible to do with the fingers, their extreme tenuity can be best realised by comparing them with some of the coarser kinds. Under the lens they look like glass or steel rods of the most precise and regular form, and in these also their com-

pound nature can be seen from the exquisitely fine lines slightly separated from the thicker fibre. The Flossy are more greasy to the touch than the Silky, and although not so brilliantly beautiful as the latter, are exceedingly soft and ductile. The nature of the asbestos fibre is thus so far identical in structure with the organic fibres already considered, that each apparently single fibre is actually composed of other still finer lines, ranged side by side, and these more minute fibres can be distinctly seen to be composed of other lines yet finer still, when higher

No. 3. Thetford Ore.

powers are used. So beautifully clear and fine are these lines when carefully drawn out that, at the suggestion of Professor Wallace, Mr. Troughton successfully employed them for micrometrical purposes, fibres of $\frac{1}{3000}$ of an inch in diameter giving an even line, and being considerably opaque.

The single fibre would not appear to possess any great degree of strength; but, in its natural form of a combination of fibres, its comparative tensile strength is in reality, like that of silk, very great indeed, and the cause of this is easily understood. But in whatever manner the fibre is examined, its rod-

like smoothness of surface, and total absence of imbrications, irregularities, or twisting, at once explains the difficulty first experienced in spinning it, without the accompaniment of some foreign substance, such as a fine thread of flax, to give it the necessary clinging power. Under polarized light there would seem to be some slight approach to knots or irregularities, but it is quite clear that, even if these in any way detract from its

Italian "Silky" Fibre.

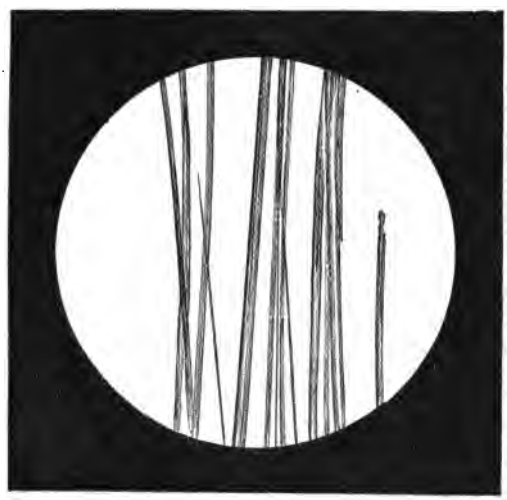
smoothness, they in reality add little, if anything at all, to its spinning qualifications.

The Italian "Grey" variety, as seen on page 224, is a coarser and altogether different fibre from any of the preceding. This, doubtless, was the kind selected by Madame Perpenti for her manufacturing experiments.

The fibres of the fine quality of Corsican asbestos, magnified like the foregoing, have a far more rod-like structure even than chrysotile, and look much like spun glass, which, in fact,

they nearly resemble in appearance; consequently they are but little adapted for spinning, but are excellently fitted for interlacement so as to lead up the flame in gas-stove fires. The colour is of a soft, delicate brown, shading off to a pearly white. The coarser quality is of a greenish white colour, and consists of bundles of shortish twists of fibres, which have a soft and greasy feel and a fair amount of tenacity.

The South African variety, from Griqualand West, although



Italian "Flossy."

very beautiful to the eye, and not at all unlike the Italian "Flossy," exhibits a very coarse and irregular appearance under the lens. The ultimate fibres in this also are of extreme tenuity. In the neighbourhood of Queenstown, South Africa, a wild plant grows in profusion, the seed vessels of which are surrounded by a profusion of fibre of extreme delicacy, beautifully soft and silky, and of some tenacity. The name of the plant I am unacquainted with, but it is strange enough and suggestive enough to form another of Africa's "surprises."

Before leaving this interesting subject it may be worth while to note an extreme illustration of the delicacy to which mineral fibres can be drawn out, which was shown by Mr. C. V. Boys, in the paper referred to. Making mention of some quartz fibres which he had drawn out to the millionth part of an inch in diameter, he says, these were of course invisible to the naked eye, but he had in actual use for some time a fibre of the ten thousandth part of an inch in diameter, and in this he found the torsion to be 10,000 times less than that of

Italian "Grey."

spun glass. These fibres, moreover, were wonderfully uniform in diameter, so uniform, indeed, that the spectrum from end to end consisted of parallel bands, whilst a spider line is so irregular that these bands are hardly observable.

And in regard to strength it appears that as the fibres become finer their relative strength proportionately increases, and actually surpasses that of bar steel, reaching in engineering language as high a figure as 80 tons to the inch, fibres of ordinary size having this strength.

And as the figures of length given can only be realized with difficulty, Mr. Boys illustrates his meaning by saying that a piece of quartz an inch long and an inch in diameter, if drawn out to the degree of fineness alluded to above would be sufficient to go all round the world 658 times, while a grain of sand just visible—say the hundredth part of an inch long and

Corsican Fibre.

an hundredth in diameter—would make a thousand miles of such a thread.*

* * * * * *

Having now drawn to a close the description of the very curious and valuable mineral with which the foregoing pages have been concerned, while scientists will have found but little in these pages which is new to them, the writer may say that his own experience has been that, generally speaking, but

* *Jour. Soc. Arts*, June, 1889.

very little is known on the subject of asbestos outside the domains of Science. He trusts, therefore, that his endeavour in this little work to give a clear and popular explanation of the mineral, and the uses to which it is applied, will tend to make it better known, and its many useful qualities more widely appreciated in accordance with its merits.

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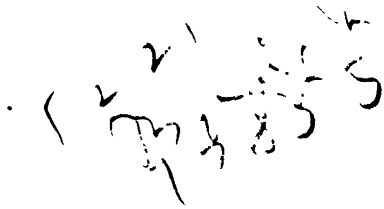

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